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Planning [and] the Sanitary City: Understanding Implications of Community-Based Ecological Sanitation Reforms in the U.S.

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PLANNING [AND] THE SANITARY CITY:
UNDERSTANDING IMPLICATIONS OF COMMUNITY-BASED ECOLOGICAL SANITATION REFORMS IN THE U.S.

A Thesis Presented

by

CATHERINE KELLY BRYARS

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DEDICATION

For Ben Goldberg, the fearless forerunner;

and for Molly McNeil Dowd, whose vivacity we remember and miss.

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ABSTRACT

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Though most commonly regarded as a revolutionary public health invention, the introduction of conventional wastewater sanitation systems has a mixed legacy in the U.S. A growing body of research links sewage-based sanitation systems with nationwide ecosystem degradation and an unsustainable dependence on vast inputs of materials and resources. In addition to contributing to chronic problems across the country, today these wastewater infrastructures are in various states of disrepair. The EPA estimates that at least $270 billion must be invested in coming years to prevent massive sanitary failures, but municipalities are increasingly unable to fund these expensive (re)investments in buried water-carriage sanitation infrastructures.

Some U.S. communities are exploring the potential for community-scale decentralized sustainable or ecological sanitation (ecosan) solutions to meet their sanitary needs at a fraction of the cost of wastewater treatment schemes and with various additional benefits. This thesis examines the first two pilot applications of community ecosan in the New England region of the U.S. to understand the opportunities, challenges, and adaptation strategies that characterize these projects in the North American context.

An emergent, mixed methods approach was developed over several years and involved personal engagement with the cases reviewed. The two pilot projects are compared and contrasted, and several themes are identified: First, the case studies indicate that specific conditions may have provided fertile contexts for the introduction of community-scale ecosan in the U.S. Second, various challenges have been posed to large scale ecosan projects in the U.S, but existing sanitary regulations and funding pathways present the most formidable barriers since they often deter innovative solutions. Third, these cases show that communities can develop myriad strategies to overcome these challenges and confront barriers to sanitation reform in the U.S.

The study is framed by an inquiry into the role of professional planners and local community members in sustainable sanitation reforms. Findings indicate that individual planners can react both positively and negatively to proposals for community ecosan schemes, and that planners possess numerous tools to support community-led programs in navigating the significant barriers they face. Ultimately, though, communities must practice self-determination in sanitation reform planning. Final recommendations suggest that future community ecosan projects focus on incremental and complementary introduction, integrate research components, and incorporate effective ecosan residuals management schemes into their programming.

PREFACE

In 1998, a chapter of U.S. sanitary history came to a close when a municipal service in Skaneateles, upstate New York ended its door-to-door collection of sanitary pails containing household sewage. The program, which had been running consistently since 1908 to provide sanitary service to 100 waterfront homes on Skaneateles Lake, functioned with dry toilets in each household that used no water for flushing or transport of human excreta. Municipal employees regularly collected sanitary collection receptacles and deposited the residuals they contained at the Syracuse wastewater treatment plant for processing (Abbot, 2004). Researchers of the Cloacina group in Portland, Oregon believe that this service, which lasted for almost a century, is the longest-running sanitary pail collection system in the U.S., and the final remnant of an era when such decentralized municipal systems were more common (Lippincott, 2010).

This recently terminated service points to a long history of sanitary planning in the U.S., before water-carriage systems for household excreta management became the standard sanitary model beginning in the late nineteenth century. The persistence of the Skaneateles case over time reminds us that despite its prevalence today, the water-borne sewage approach to sanitation has been a relatively recent invention of human society. And yet, by the early twentieth century the sewer-or-septic approach was the preferred solution of many communities in the U.S. Later in the century regulations and funds established by federal legislation made municipal wastewater treatment schemes universal in most areas of the country, and since then many U.S. communities have not looked beyond the convenience of the sewer for their sanitary needs… until very recently.

The last few years have seen a rise in curiosity about alternatives to conventional sewer and septic schemes, since wastewater sanitation schemes are increasingly critiqued as expensive, harmful to the environment, and inefficient. This thesis documents the experiences of two communities that have piloted projects in community-scale ecological sanitation (ecosan). Ecosan systems, which require little-to-no water and use ecological processes to treat human excreta, offer advantages over conventional sanitation but also present challenges inherent in innovative implementation.

The first case describes work of the Rich Earth Institute non-profit group in Brattleboro, Vermont, which has coordinated the collection of over 10,000 gallons of anthropogenic urine since 2012 for experimental field trials in the fertilization of hay and human food crops on family farms in the state. The municipally-run Falmouth Eco-Toilet Demonstration Program in the town of Falmouth on Cape Cod, Massachusetts has subsidized and administered the installation of about 10 residential eco-toilet systems to assess their viability as a sustainable alternative to coastal sewering. Both pilot projects have involved rigorous research components and a range of alternative toilet models.

These projects are the first of their kind in the U.S., and have revealed both promising opportunities and considerable challenges for adopting community-scale ecosan in the U.S. context. Though the future of these programs is uncertain, their importance is unmistakable. They point to decisive flaws in dominant sanitation practices as well as to the struggles of communities across the U.S. seeking to improve, or simply maintain, their access to sanitation systems that meet their needs and budgets.

The findings presented in this thesis reveal shared characteristics between the two community ecosan initiatives studied, a most important quality being the community-initiated, or 'grassroots,' aspect of these programs. Emergent trends towards the reformation of sanitary practices in the U.S. can reflect myriad community interests, including concerns for environmental and economic justice. For example, a slogan used by citizens in Falmouth, Massachusetts captures an economic concern fueling their local campaign for eco-toilets: "$EWER$: The Meek Shall Inherit the Debt." If such concerns motivate more communities to pilot innovative and alternative sanitation solutions, then town and city planners will be obligated to develop opinions and strategies related to sanitation planning reform. This thesis aims to provide an initial resource to such communities and to the professionals that serve them.

TABLE OF CONTENTS

Page

LIST OF TABLES

Table Page

LIST OF FIGURES

ACRONYMS

ANR: Agency of Natural Resources of Vermont
ASCE: American Society of Civil Engineers
BCDHE: Barnstable County Department of Health and Environment of Massachusetts
BSEPGF: Board of State Examiners of Plumbers and Gas Fitters of Massachusetts
CCC: Cape Cod Commission
CEC: Contaminants of Emerging Concern
CSO: Combined Sewer Overflow
CWMP: Comprehensive Wastewater Management Plan of Falmouth
EPA: Environmental Protection Agency
IAPMO: International Association of Plumbing and Mechanical Officials
IWMEA: Insignificant Waste Management Event Approval granted by Vermont Department of Environmental Conservation
MassDEP: Massachusetts Department of Environmental Protection
O&M: Operations and Management
PAR: Participatory Action Research
PPCP: Pharmaceuticals and Personal Care Products
R&D: Research and Development
REI: Rich Earth Institute
SARE: Sustainable Agriculture Research and Education program of the USDA
SSO: Sanitary Sewer Overflow
TMDL: Total Maximum Daily Load
UD: Urine Diversion
UDDT: Urine Diverting Dry Toilet
UNRP: Urine Nutrient Reclamation Project of the Rich Earth Institute
USDA: U.S. Department of Agriculture
VPA: Vermont Planners Association
WERF: Water Environment Research Foundation
WC: Water Cup, a water-based flush toilet
WQMC: Water Quality Management Committee of Falmouth, Massachusetts
WWTF: Waste Water Treatment Facility

KEY TERMS

Sanitation – According the World Health Organization, "Sanitation generally refers to the provision of facilities and services for the safe disposal of human urine and feces" (WHO, 2015). In some cases the term *sanitation* additionally incorporates delivery of treated water for household or community consumption, but for the purposes of this paper *sanitation* will refer only to the first definition unless otherwise specified.

Sustainable Sanitation – The international advocacy network Sustainable Sanitation Alliance (SuSanA)'s definition of sustainable sanitation is paraphrased in Rosemarin et al. (2012): a sustainable sanitation system is one that "protects and promotes human health, minimizes environmental degradation and depletion of the resource base, and is technically and institutionally appropriate, socially acceptable, and economically viable also in the long term (p. 5).

Ecological Sanitation / Ecosan – This sustainable sanitation approach encompasses a range of low-cost alternative toilet systems that use little to no water to flush human waste and additionally produce water, renewable energy sources or soil amendments as beneficial use products from human excreta residuals. The First International Conference on Ecological Sanitation, hosted in Nanning, China in 2001, defined ecological sanitation as "sanitation systems that prevent pollution of the environment, destroy pathogenic organisms in human feces and urine, and return the nutrients in urine and feces to the soil" (IEES, 2001). This thesis will refer to ecosan toilet systems, sometimes called eco-toilets, which include urine-diverting models that source-separate urine from feces to facilitate the efficient treatment and beneficial reuse of human urine and feces.

Community-scale – For this paper I distinguish *community* ecosan systems from individual or household ecosan systems. My definition of community-scale ecosan refers to decentralized systems that surpass a scale that would be considered private or individual to involve a network of people sharing responsibilities, costs, or resources, and which may include a public installation. Communal or public aspects of these systems can involve shared management, collection, transfer, treatment or beneficial use schemes. Throughout this paper, I often substitute the term 'large-scale' to refer to these ecosan systems that function at a scale beyond the individual household model.

Nutrient Pollution / Eutrophication – This term refers to excess concentration of nutrients such as nitrogen and phosphorus in water. This pollution is often caused by fertilizer runoff or discharges of untreated or partially treated wastewater into the environment. The EPA explains, "Nutrient pollution is one of America's most widespread, costly and challenging environmental problems," and yet few Americans realize its vastly damaging effects (EPA, 2015). When not addressed, nutrient pollution leads to hypoxia conditions in water ecosystems where oxygen is depleted to the extent that fish and other organism populations crash. Over long periods of time, nutrient pollution creates coastal 'dead zones.' There are already more than 400 dead zones worldwide, with the largest dead zone occurring off the US coast in the Gulf of Mexico (Diaz & Rosenberg, 2008).

Conventional Sanitation: Conventional sanitation approaches in the US are typically water-based sanitation systems that use flush toilets to connect with buried water carriage networks that are pumped to either centralized (sewage treatment plant) or decentralized (onsite septic tanks or small-scale shared water treatment nodes such as mound systems) sites for treatment and discharge to the environment. Primary treatment uses mechanical processes to remove solids from the wastewater stream, secondary treatment uses biological processes to break down organic matter in the sewage, and tertiary treatment includes any treatment beyond secondary treatment and can include the removal of nutrients, disinfection with chlorine or other chemicals, or even treating the wastewater to drinking water standards (World Bank Group, 2015).

Nutrient Recovery / Urine Reclamation / Pee-cycling / Urine Diversion – Nutrient recovery is the recapture of mainly nitrogen and phosphorus nutrients in waste streams for beneficial reuse. Strategies for the source separation of human urine have developed to capture urine nutrients before they enter the wastewater stream. Diverted human urine can contain as much as 10 lbs. of nitrogen per person per year and nearly 1 lb. of phosphorus per person per year. The practice of 'pee-cycling' reclaims these abundant nutrients for application in settings where animal manures or synthetic fertilizers are currently used, as well as for other industrial purposes.

Path dependence – This concept can be summarized as the realization that 'history matters' when determining current and future directions in development and planning. The concept is relevant to discussions of sanitation since past investments in large-scale water carriage and sewage treatment infrastructures place pressure on communities to continue to invest in these solutions. The term path dependence will be applied in this paper to explain why US pathways for the regulation and financing of sanitary infrastructures privilege wastewater infrastructures at the exclusion of more innovative solutions.

CHAPTER 1

INTRODUCTION

1.1 The Sanitary City: At an Impasse

> *"[Sanitary] service delivery…often blends so invisibly into the urban landscape; it is part of what we expect a city to be. While economic forces are essential to the formation of cities, urban growth depends on service systems that shape the infrastructure and define the quality of life… To function effectively the American city has to be a sanitary city."*
>
> - Martin V. Melosi, *The Sanitary City* (2008)

In 2008, urban historian Martin V. Melosi published *The Sanitary City*, his mammoth work documenting the history of sanitary service delivery in the U.S. Over the course of the book, Melosi describes how sanitation systems have developed in ways that embody predominant and evolving understandings of public health and disease through centuries of U.S. history. Despite the fact that bacterial and ecological framings of disease have improved upon earlier, archaic ideas of filth-related miasma, however, sanitary systems for managing human excreta have not evolved accordingly (Melosi, 2008).

The result is that the logic of today's sanitation systems is contrary to modern understandings of public health and environmental stewardship by reflecting outdated notions of disease that prevailed in the 19th century. Contemporary sanitation practices based on prodigious use of water to transport human urine and feces away from homes and businesses create sewage, which in turn becomes a persistent problem for U.S. communities since its subsequent remediation requires expensive transport, processing and elimination infrastructures (George R. , 2008; Tarr, 1984).

The planning of sanitary systems that better serve the public and protect the nation's ecosystems from water-borne pollutants has been complicated by the entrenched nature of physical sanitary infrastructures and the institutions that developed to support ongoing function of these public investments. This intrinsic momentum of infrastructure, often referred to as path dependence, has prevented major reforms of sanitary practices to the present day. However, increasing levels of environmental degradation and infrastructural decay are pushing some U.S. communities to innovate radically new sanitary solutions for their towns.

This thesis examines experiences of the first two pilot projects in the country to formally trial the application of ecological sanitation (ecosan) schemes, some involving urine-diversion components, at the community scale as an alternative to conventional wastewater sanitation. This community-initiated approach to sanitation planning in the U.S. reflects the broader devolution of sanitation planning responsibilities to the municipal level since the late 20th century. As local communities assess their sanitation options over the next few years, professional planners will have to decide how to best accompany these local processes.

Melosi concludes his classic work with the seemingly obvious reflection that American cities must be sanitary cities or they will cease to meet the needs of their citizens. However, Melosi offers this critical observation at a moment when the U.S. *Sanitary City* finds itself at an impasse: U.S. citizens can either choose to reinvest in flawed conventional sanitation systems or design and adopt more affordable and resilient, but as of yet unproven solutions for their communities. This thesis meditates on this sanitary impasse and the ecosan approaches some communities have begun to trial locally to experiment with novel conceptualizations of the *Sanitary City*.

1.2 Scope of Thesis

This thesis combines literature reviews and two case studies to better understand (1) how and why innovative sanitation practices are occurring in the US; (2) what, if anything, these developments have to do with the planning field; and (3) what lessons pilot projects have revealed to date in terms of opportunities and barriers for ecosan implementation in the U.S., as well as potential strategies for navigating challenges.

1.2.1 Research goals

Firstly, this thesis aims to promote consciousness of the sanitation challenges facing communities in the U.S., and about alternative sanitation technologies proposed to address these problems. Secondly, as a research project pursued under the aegis of a regional planning program, the thesis asks what role planners might have in assessing and reforming U.S. sanitation systems to better serve the public in general as well as specific communities in which professional planners work. Thirdly, I have framed my study of two pilot programs trialing alternative sanitation schemes to produce information that will be helpful to these projects moving forward. I hope that the findings here contained may serve other communities similarly struggling to identify viable pathways toward improved sanitation practices for present and future generations.

In terms of its contribution to ongoing discussions in the academy, this report responds directly to a call in a 2011 paper produced by the Water Environment Research Foundation (WERF) on the applicability of urine diverting (UD) ecosan schemes in the U.S. The study concluded that research and demonstration (R&D) projects must be initiated and studied to generate the most basic information on how U.S. communities react to and manage such schemes (Fewless, Sharvelle, & Roesner, 2011). My observations and conclusions aspire to inform these discussions and advance a research agenda to understand broad sanitation reforms underway in the U.S. today.

1.2.2 Limitations

The limitations of this study are numerous. The emergent, immersed and mixed methods that I employed to gather information on the pilot programs studied are likely very difficult, if not impossible, to replicate. In addition, they reflect my inherent bias to support and advance the trialing of alternative sanitation approaches in U.S. communities in the interest of identifying the best and most appropriate sanitation practices of the future.

There were also significant limitations in my ability to gain access to program participants in each case. In the case of REI, the organization's discretion policy did not permit me to directly contact participants in a randomized manner. In the case of Falmouth, I was unable to pursue site visits and conversations with a significant number of participants due to time and mobility constraints. Future research would be advised to investigate what additional insights in-depth interviews with participants can reveal about program management, public and participant perceptions, and overall satisfaction with the program and UD ecosan technologies used.

Ultimately, I use findings from the case studies to generalize about broad trends in sanitation planning in the U.S. In some respects, the experiences of just two communities are not sufficient to justify such generalization. Since the programs studied are currently the only two of their kind in the U.S. at this moment, though, and there is considerable demand for information about their operations and what they reveal about broader trends in the U.S., I offer my study and conclusions with a caveat. My findings and resulting suggestions represent just an initial step toward understand these programs, and further research would need to expand upon and enhance the data compiled here.

1.3 Research Questions and Hypotheses

Several questions have motivated and oriented this thesis project over time:

Questions: How has the planning field dealt with or related to issues of sanitation—historically and today? What implications do innovative, community-based sanitation practices have for the work of planning professionals and scholars? Is the planning profession necessarily relevant to sustainable sanitary reform in the U.S.?

- ***Claim***: Early forms of sanitation planning provided foundations for establishment of the planning profession, though this history is not often reflected in the field's scholarship or in modern planning practice.

- ***Claim***: The community-based and sustainability characteristics of emergent sanitation reforms in the US are aligned with the values of the planning profession and warrant awareness and critical consideration.
- ***Claim:*** Though planners are well-positioned to support sanitation reform with the tools available to them, involvement of professional planners is not necessary for community-based projects to initiate and succeed in the short term.

Question: Why and how does ecological sanitation appeal to some US populations, specifically its implementation at the community-scale?

- ***Claim***: Numerous and differing factors can motivate communities to pilot ecosan toilet systems. In accordance with unique motivations and contexts, pilot projects can initiate, formalize, and operate differently, while also sharing certain similarities.
- ***Claim***: Community-scale application can appeal to communities because it triggers an economy of scale that reduces individual costs and responsibilities for owning and operating an ecosan toilet system.

Questions: What barriers have the pilot projects in community-scale ecosan encountered, and what strategies have developed to overcome these challenges? How might lessons learned influence ongoing and future initiatives?

- ***Claim***: Institutional (regulatory, fiscal) and socio-cultural (public acceptance, program management, etc.) barriers can present challenges to pilot ecosan project development. Strategies can be developed to overcome some obstacles, but entrenched institutional pathways and path dependence currently constitute significant barriers to long-term stability of these initiatives.

Questions: What is the future of sanitation reforms in the U.S.? Given that groups currently interested in community-scale ecosan practices represent a narrow and privileged group in the U.S., how should ecosan solutions be framed as the agenda for sanitation reform progresses in the U.S.?

- ***Claim:*** Though the future of community ecosan projects is not clear at this point, current trends indicate that interest in sanitary reforms involving alternative sanitation approaches is on the rise in the U.S.
- ***Claim:*** On the one hand, privileged group interests in sustainable sanitation approaches may have a normalizing impact on otherwise fringe practices. On the other hand, ecosan advocacy groups should strive to frame ecosan solutions as complementary to ongoing sanitation practices and not as universal system conversions if they wish for projects to be received and implemented widely.

1.4 Methods

An emergent, mixed and action-oriented research methodology was developed for this investigation over the course of several years. Mixed methods combined in the study include case study and literature review components. More details on development of the comparative case studies analysis are provided at the beginning of Chapter 4. I gathered information on the case studies through long-term direct participant observation, informal conversations with program directors and participants, and consultation of documents and reports realized in connection to program operations.

My involvement in one of the case studies, the Rich Earth Institute (REI) program, was more in-depth than with the second case study, the Falmouth Eco-Toilet Demonstration Program. I accompanied internal processes of REI from its inception in 2011 as a founding board member of the group and later as an intern with the program. Figure 1 shows pictures of my participation in promotional activities and meetings with state regulators for the project.

To better understand the theoretical underpinnings of action-oriented research methods, I reviewed the contributions of Fals-Borda and his ideas about participatory action research (PAR). An aspect of this approach that has been particularly influential on the development of my methods is the goal to deconstruct barriers between the researcher and their research subjects. According to Fals-Borda, an 'asymmetry' dividing researchers from their subjects is characteristic of traditional academic approaches and is counterproductive in research with goals for furthering social justice and community empowerment (Fals-Borda, 1991, p. 4). Throughout my investigation, I have interacted with and contributed to the programs when possible as an engaged and supportive community member.

It is interesting to note that action research methods have previously been applied to investigate transitions from conventional to sustainable sanitation systems (Sankaran, Abeysuriya, Gray, & Kachenko, 2015). Sankaran et al. argue that action-oriented methods are advantageous in the study of sanitation issues because they allow for a complex systems thinking approach that precludes dualist interpretations of sanitation systems as either technical or socio-cultural problems, which allows for more complex truths about sanitation systems to be elucidated.

Figure 1: Researcher engaged in action-oriented program immersion

1.5 Thesis Outline

The thesis is organized into three broad sections: literature reviews, case study findings, and discussion and conclusions. Chapters 2 and 3 introduce central themes of the thesis. Chapter 2 briefly examines the historical relationship between the planning profession and the coordination of sanitary structures in the city. Chapter 3 delves into the current failings of conventional wastewater systems and the relative advantages and disadvantages of ecological sanitation arrangements. This chapter explores why ecosan approaches are appealing to some U.S. communities.

Chapter 4 presents the case studies on the REI program in Brattleboro, Vermont, and the Falmouth Eco-Toilet Demonstration Program in Cape Cod, Massachusetts. The section opens with an explanation of the case study design and closes with a comparative analysis of the two programs.

Chapters 5 and 6 use findings from the case studies to articulate lessons learned from the first pilot projects of urine diversion (UD) ecosan implementation in the U.S. Opportunities, challenges, and adaptation strategies are discussed, as well as the role of professional planners and average citizens in pursuing sanitary reforms at the community level. The final chapter outlines brief recommendations, directions for future research, and closing thoughts from the researcher.

CHAPTER 2

PLANNING THE SANITARY CITY: PAST AND PRESENT

> *"Developing interventions in the planning process to promote sustainable development can only be done through understanding the history of how current urban infrastructure systems have been planned and how this shapes today's infrastructure planning."*
>
> *- Malekpour et al. (2015)*

2.1 Opening

Though arguably the most intellectually compelling debates in the planning field today deal with issues of communication, question the nature of democracy, and theorize the meaning of justice in the (multipli)city, the work that originally inspired the planning profession was more oriented toward defining the city's physical form. In fact, according to the influential planning analyst Peter Hall, the planning profession focused mainly on managing the physical form of urban centers until as late as the WWII era (LeGates & Stout, 2011).

Sanitary reforms of the 19th century represented some of the first iterations of centralized physical planning that laid foundations for consolidation the professional planning discipline. Yet how do planners interface with sanitation planning and other physical planning projects today? This question becomes more relevant in the face of widespread infrastructure degradation in the U.S. and little visible public movement to comprehensively improve or reform these necessary components of the city.

2.2 Planning and Sanitation: Common Origins

Since the birth of Chadwick's Sanitary Idea in nineteenth century England, cities and the professionals who plan them have been charged with coordinating infrastructures for the hygiene and health of the public. In the U.S., widespread adoption of sanitary sewers displaced myriad decentralized methods to become the dominant approach to municipal sanitation at the close of the nineteenth century and beginning of the 20th century (Melosi, 2008; Tarr, 1984). Reforms altered the built environment of the city so extensively and permanently that sanitary services became vital to urban life as the "circulatory system of the city" (Melosi, 2008, p. 1).

During the reform era, sanitary interventions took the form of 'special purpose planning', also called functional planning, and addressed specific topical concerns rather than taking a holistic approach characteristic of the rational planning paradigm of the twentieth century (Neuman & Smith, 2010, p. 26). By introducing and institutionalizing the idea that centralized authorities could undertake large-scale interventions in the public realm on behalf of the public good, these reforms paved the way for the rise of the modern planning profession and some historians consider these interventions to be the earliest manifestations of city planning (Neuman & Smith, 2010; Peterson, 1979). Peterson (1979) writes that while these early efforts in urban reform are not synonymous with modern iterations of urban planning, sanitary reforms were certainly a "stimulus to city planning" and "to the extent that they advocated systematic, large-scale reshaping of cities, sanitary reformers functioned as city planners" (p. 84).

Following the introduction of massive sanitary projects across the United States, the profession of urban planning began its trajectory toward formalization during the first decade of the twentieth century. Formal and comprehensive plans like those characteristic of the City Beautiful movement quickly "expanded planning's scope beyond infrastructure and hygiene," and an impulse to differentiate planning from associated professions like public health and engineering lead planners to adopt the tool of zoning as their unique contribution to urban design (Neuman & Smith, 2010, p. 27). Formalization of planning as a specialized profession in the first half of the twentieth century ultimately downplayed much of the planning field's roots in piecemeal physical planning and sanitary reforms. Despite this shift, though, some planning scholars have insisted on recording and valuing the discipline's roots in the Sanitary Reform Era (Ibid).

2.3 Planners and Sanitation: In Conversation Today?

Recently, some scholars have called for the planning field to seek a "decisive reengagement with infrastructure planning" (Neuman & Smith, 2010, p. 23). This plea for reconciliation is rooted in concerns for contemporary deterioration of public infrastructures in the U.S. and the need for multidisciplinary perspectives and holistic planning to solve complex problems of the modern metropolis. Additionally, scholars have identified several aspects of early sanitation planning that provide insight to the nature of an effective planning praxis (Corburn, 2007; Neuman & Smith, 2010).

For example, Peterson (1979) argues that by demonstrating the relative efficiency and efficacy of incremental and gradual sanitation projects over comprehensive urban remodeling, “Sanitary reform, in short, had anticipated the triumph of specialized, limited-purpose urban planning over a more comprehensive vision” (p. 95) long before planning scholars theorized the advantages of incremental planning (Lindblom, 1959). Additional practical insights about the nature of cities and their publics have been identified from earlier eras when planners dealt more directly with the physical urban form and lived realities of the city, leading several scholars to argue that the discipline should embrace, rather than dismiss, planning’s historic roots (Neuman & Smith, 2010; Eisenman, 2013).

Discussions in the field of public health have similarly called for a recovery of the shared history that catalyzed planning and public health practices alike. In the last two decades in particular, a call to ‘reunite’ the planning and public health fields to confront contemporary concerns for public well being has drawn considerable attention and support and generated ongoing discussions in the academic literature (Corburn, 2007; Duhl & Sanchez, 1999; Greenberg, Popper, West, & Krueckeberg, 1994; Perdue, Gostin, & Stone, 2003; Sloane, 2006;). These writers often argue that the specialized skills and perspectives of each discipline should be reacquainted to more effectively resolve today’s complex urban health dilemmas.

A number of complex environmental health complications, such as nutrient pollution and the introduction of pharmaceuticals and other human-made chemicals into the environment, affect U.S. communities across the country and are linked to dominant wastewater practices. Though water-based systems undoubtedly improved public health and quality of life in the U.S. as coverage of buried pipe systems spread rapidly throughout the last century, the ongoing generation of sewage has caused long-term problems not originally foreseen (Condran & Crimmens-Gardner, 1978; Bernhardt et al., 2008; Black & Fawcett, 2008). The role of planners in addressing what has been considered a public environmental and infrastructural crisis is not yet clear (EPA Nutrient Innovation Task Group, 2009; Melosi, 2008).

2.5 Closing

According to Black & Fawcett (2008), Sir Ronald Ross, the winner of the Nobel Prize for Medicine in 1902, said of sanitation:

> "Great is sanitation, the greatest work… that one can do. What is the use of preaching high moralities, philosophies, policies and arts to people who dwell in appalling slums? …We must begin by being cleansers."
> Sir Ronald Ross as quoted in (Black & Fawcett, 2008)

Despite the profession's roots in sanitary reforms, scholars argue that planners have become estranged from the more practical aspects of urban planning as concerns for social and justice planning have taken center stage. But if Melosi is right in claiming that "to function effectively the American city has to be a sanitary city," then what responsibility do planners have to reclaim their roots in physical planning of the city to aid communities in reforming sanitation planning from the ground up (2008, p. 263)? The remainder of this thesis meditates on this question and ultimately offers suggestions for how professional planners may best support communities facing difficult decisions about how to manage or reform failing sanitary systems in the U.S.

CHAPTER 3

THE RISE OF SANITATION ALTERNATIVES: COMMUNITY ECOSAN

3.1 Opening

> *"I've been involved in this for 20 years…The city studied it and studied it, then decided it was too expensive [to fix the CSO problem]. The problem here is that people have put up with it for so long that they essentially have gotten used to it."*
>
> - Indianapolis resident quoted in *Planning* article (Jacobson, 2000)

Combined sewer overflows (CSO), which dump sewage and even industrial wastes into open waterways when the capacity of stormwater systems are overwhelmed, are just one example of how conventional sanitation systems regularly pollute U.S. ecosystems and communities today. Commentary from a citizen of Indianapolis alludes to the persistent difficulties cities face to alter conventional sanitation systems due to high costs of modifying entrenched infrastructures and processing practices. The comments also point to an issue arising from long-term dependence on inflexible and deteriorating infrastructures: communities can feel powerless to improve upon the shortfalls of wastewater sanitation systems.

Recent developments show that not all communities feel disempowered to improve their local sanitary conditions through drastic modifications, however. This chapter provides context to understand why and how alternative, sustainable sanitation approaches are gaining attention in some U.S. communities. The following chapter will delve into the specific experiences of projects experimenting with community-scale adoption of UD ecosan schemes to reform sanitary planning in their towns.

3.2 Conventional Sanitation: Accumulated Consequences of Sewage

The popularization of flush toilets and buried water carriage drainage systems in North American towns in the 19th and early 20th centuries introduced new experiences of cleanliness and health to the American household. Yet the long-term consequences of investing in water-based sanitation systems would become clear by the mid-20th century when problems of aging infrastructures and environmental pollution levels were becoming impossible to ignore (Melosi, 2008; Tarr, 1984). Federal regulatory and financial legislation revitalized conventional sanitation infrastructures at the time, but U.S. communities find themselves faced with serious degradation in local environments and infrastructures again today (George R. , 2008).

3.2.1 Ailing Infrastructures

Today the buried pipe networks installed to provide sanitation to communities across the U.S. are in various states of deterioration and are poised for widespread failure if not improved or replaced in coming decades (Younis & Knight, 2010). Repair of degraded sewer pipes alone, some of which are more than a century old in North America, consume 50-75 percent of all costs for wastewater management in the country (Marlow et al., 2013). Wastewater treatment facilities (WWTF) are similarly in need of repairs and upgrades to sustain or expand capacity and to include new remediation technologies into their processing schemes

(Ariaratnam & MacLeod, 2002; Halfawy et al., 2008). Extensive problems associated with maintaining sewer infrastructures have also been documented in England, the symbolic birthplace of the modern wastewater paradigm, where over 94% of the population is serviced by sewer networks, as well as in other parts of Europe (Bishop et al., 1998; Reynolds & Barrett, 2003).

The American Society of Civil Engineers projected in 2013 that the costs for replacement, repair, and expansion of U.S. wastewater infrastructures would total $280 billion over the following twenty years, and EPA estimates have mirrored these figures (ASCE, 2013; EPA, 2007). Though more studies are needed to understand how modern municipalities are navigating these maintenance requirements in the U.S., experts agree that the costs of wastewater treatment reinvestments are colossal and increasingly unaffordable for local communities to shoulder (EPA Office of Water, 2015; Termes-Rifé et al., 2013). Additionally, with life cycles of no more than 50-75 years, sewers can present an undesirable investment for municipalities. Communities can foresee having just finished paying off major sewer or WWTF updates when an upgrade, repair or replacement will be necessary again (Lettinga et al., 2001; Younis & Knight, 2010).

Decentralized wastewater solutions can offer significant financial savings over centralized sewer systems that require great infrastructural investments to link distant collection and treatment nodes (Lettinga et al., 2001; Von Hauff & Lens, 2001). The most common decentralized wastewater system, a septic system, collects and stores household sewage onsite in buried tanks that require regular emptying. Like sewers, septic systems involve significant costs and eventually fail and require replacement. Though the EPA reports that new septic systems cost less than $10,000, full installation costs, which involve pumping and piping components and nitrogen removal technologies, can reach or surpass $20,000 (EPA SepticSmart, 2012; Rich Earth Institute, 2015). Failure of septic systems can occur when residential density increases and septic discharges overwhelm soils and subsurface water flows (Cape Cod Commission, 2015; Howarth, 2008).

In previous years, municipal sanitation costs were heavily subsidized through federal grants as part of Clean Water Act legislation passed in the 1970s, but in the late 1980s these federal grants were altered to function as revolving state loans, and municipalities today are struggling to finance required improvements to their systems (Melosi, 2008). This harsh financial reality is combining with concerns for sustainable development to push some U.S. communities to identify alternatives to centralized sewering for their sanitation needs.

3.2.2 Polluted Waterways and Resource Inefficiencies

Wastewater management contributes to a series of environmental and public health problems, the severity of which is often insufficiently documented or understood (EPA Nutrient Innovation Task Group, 2009; EPA Office of Water, 2015). The result is that over half of US waterways are impaired to the point that they "do not support healthy populations of aquatic life" (EPA , 2013). Over 78 percent of US coastal waters currently experience eutrophication associated with wastewater management practices, and projections of population growth in the US suggest these grim conditions are likely to further deteriorate in the 21st century (EPA Nutrient Innovation Task Group, 2009). Many studies predict climate change impacts such as sea-level rise and severe precipitation events will introduce new strains on wastewater infrastructures in coming years leading to higher levels of contamination and failure, especially in coastal locations (Flood & Cahoon, 2011).

Nutrient pollution, which has been called "one of the costliest, most difficult environmental problems we face in the 21st century," has been directly connected to failings of wastewater management schemes (Boesch, 1999; EPA Nutrient Innovation Task Group, 2009, p. 1). Though in most areas of the U.S. agricultural inputs are the greatest contributor to nutrient pollution, in coastal areas such as Cape Cod, MA, about 60-80% of the nutrients causing pollution of ground and surface waters come from sewer and septic systems (Cape Cod Commission, 2015; Howarth, 2008). Extreme concentrations of nitrates in drinking and surface waters can even threatening the health of infants who develop methemoglobinemia, or blue baby syndrome, as a result of prolonged exposure, though to date these events are rare in the U.S. (Wang et al., 2013). If separated from wastewater streams, the nutrients causing pollution could be used to meet worldwide demand for agricultural nutrient inputs, particularly phosphorus, but these resources are currently lost through wide dispersal (Mihelcic, Fry, & Shaw, 2011).

Pathogen and nutrient pollution occur through both major sewer overflow events and ongoing filtration processes. Aging sewer pipes contain fractures that allow for sewer leakage, known as sewage exfiltration, which causes widespread environmental and public health problems when human pathogens and nutrients are released into ground and surface waters. Though sewage contamination is often associated with major precipitation events and stormwater sewer overflows, a recent study demonstrates that sewage exfiltration contaminates public water extensively even during periods with low precipitation activity (Sercu et al., 2011). Septic systems, which are designed to slowly discharge regular amounts of septic effluent underground over time, cause significant pollution problems when density of the systems increases to a level that overwhelms local ecosystem metabolism to absorb and process nutrients (Cape Cod Commission, 2015; Howarth, 2008). Currently septic systems serve about one in four homes in the US, and sewers serve the majority of the remaining population (EPA SepticSmart, 2012).

When communities repair failing septic or sewer systems to prevent pollution, they are required to upgrade to higher treatment standards than were previously required of previous installation. 'Sewer rehabilitation' or 'renewal planning' for sewers necessitates the purchase of new and expensive technologies to remediate biological and nutrient pollutants. Costs for these investments can easily reach billions of dollars, placing considerable stress on local communities and even dissuading communities from updating their treatment systems (Ariaratnam & MacLeod, 2002; Cape Cod Commission, 2015; Halfawy et al., 2008). The extreme costs of advanced wastewater treatment have caused some to question the overall viability of wastewater approaches. A study recently done in Australia showed that tertiary wastewater treatments produce a net loss for society when costs incorporate environmental impacts and other externalities, which can total several hundred million dollars per year (Hardisty et al., 2013).

The financial tolls that wastewater pollution and preventative treatments take on U.S. communities are higher than they have ever been. Though an EPA task force recently concluded that investments in pollution prevention are much less costly than subsequent remediation (EPA Office of Water, 2015), the best strategies to prevent pollution are not evident. For these reasons, some U.S. communities are looking into economic and ecological advantages that alternative sanitation solutions may pose.

3.3 Ecological Sanitation: Advantages and Limitations

Sustainable sanitation methods have a substantial history of application in the U.S. However, installation of these systems has heretofore been largely limited to use in private buildings and residences, exclusive eco-villages, and have sometimes involved informal and unregulated practices (Allen & Conant, 2010). For the first time, U.S. communities are formally testing the idea that ecosan solutions involving communal or municipal management schemes can meet sanitation needs of the general public in more sustainable and efficient ways than conventional wastewater treatment. This section provides background on concepts of ecological sanitation, its advantages and limitations relative to dominant practices, and its application in some contexts.

3.3.1 Key Concepts

Discussions about alternative sanitation typically reference sustainable and ecological sanitation philosophies. Sustainable sanitation, also called environmental or ecological sanitation in various contexts, generally refers to sanitation practices that are more efficient, environmentally responsible, and affordable than conventional practices (SANDEC and WSSCC, 1999; SuSanA, 2016). Ecological sanitation (ecosan) refers more specifically to sanitation systems that occupy little to no water, rely on ecological methods to treat human urine and feces, and produce beneficial use products from sanitary residuals (Esrey, 2002; Winblad & Simpson-Hébert, 2004). Sustainable and ecological sanitation approaches value ideas about 'closing the loop' between agriculture and sanitation systems by reclaiming nutrients from human excreta as agricultural inputs. This disconnect between natural, 'closed' agriculture nutrient cycles in the rural sphere and 'open' urban nutrient flows has long been recognized , and has been theorized through urban metabolism frameworks (Brands, 2014; Giradet, 1999), and even formed some of the basis for Marx's critique of capital (Foster, Clark, & York, 2011).

Ecosan systems can involve a range of collection methods and treatment procedures to capture and process human excreta, and are applicable in both rural and urban settings (Mara, 1996; Winblad & Simpson-Hébert, 2004). System components can be combined to produce toilets with self-contained or centralized, multi-chambered or single-chambered, waterless or micro-flush, urine-diverting (UD) or mixed collection, and single-storey or multi-storey designs (Anand & Apul, 2014). Systems can be retrofitted intoto existing buildings or designed comprehensively in new constructions (Del Porto & Steinfeld, 2000).

Ecosan systems often incorporate UD components to faciliate the dessication of feces and to enable the reuse of nutrients concentrated in human urine. UD arrangements use special toilet bowls or isolated urinals to separate urine from feces and from wastewater streams at the source (Steinfeld, 2004). Source-separated urine can be stored along with feces in composting toilets or can be stored independently in storage tanks. Two UD arrangements are represented graphically in Figure 2 below.

The first diagram shows a UD scheme incorporated with a flush toilet system. In this arrangement, feces are eliminated together with wastewater as in a conventional sanitation system. The second diagram shows UD installation with a waterless toilet that sequesters feces separately from urine. In both cases, urine is stored onsite in storage tanks. The two U.S.-based cases of community-scale ecosan implementation reviewed in Chapter 4 have promoted such UD arrangements in New England towns.

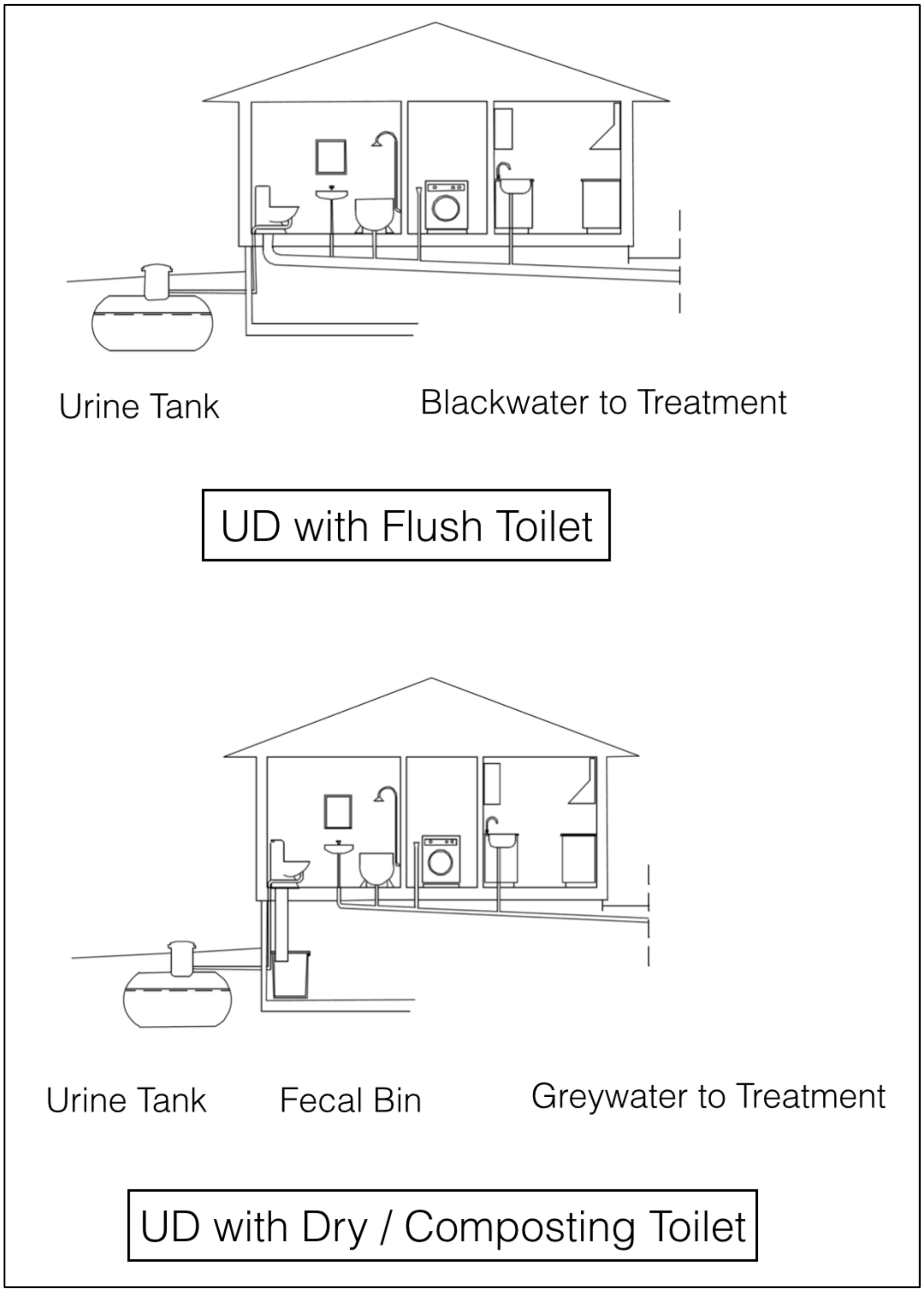

Figure 2: UD Arrangements for Flush and Dry Toilets. Adapted from (Lennartsson & Ridderstolpe, 2001).

Implementation of ecosan systems to date has been pursued mostly in the context of developing countries, with installations in the Global North being limited to mostly European and particularly Scandinavian countries. Lack of formalized implementation in North America is reflected in and connected to a dearth of academic investigation into the subject. Only in the last two years have U.S.-based scholars begun to publish studies in academic journals about ecosan applications in developed contexts (Anand & Apul, 2014; Brands, 2014; Schoen, Xue, Hawkins, & Ashbolt, 2014; Wood, Blackhurst, Hawkins, Xue, Ashbolt, & Garland, 2015).

Information about ecosan systems in theory and in practice is largely sourced from investigations performed outside of the U.S. Accordingly, U.S.-based scholars performing research on ecosan have had to depend heavily on the grey literature to supplement academic reports (Anand & Apul, 2014). This thesis has done the same.

3.3.2 Advantages

Proponents of ecosan argue that the systems offer a number of advantages over conventional sanitation approaches. Advantages include more resilient modular installation, less resource intensive operation, pollution prevention, and the conversion of human excreta into renewable resources.

Decentralized Operations: Unlike conventional sanitation systems that rely on piped water carriage networks to convey urine and feces from one location to another, onsite ecosan systems can be relatively self-contained. Decentralized installations and operations reduce the need for material-intensive infrastructures. The decentralized nature of ecosan systems make them more resilient and adaptable compared to the highly immutable structures of water-based methods (Esrey, 2002). Since ecosan systems by definition are not limited to any specific design or technology, systems can be adapted to social, economic and environmental conditions of any given context (Werner, Panesar, Rud, & Olt, 2009).

Resource Efficiency: Less material inputs needed for infrastructure to connect toilet installations with centralized processing and treatment centers reduces the need for conveyance components in ecosan schemes. Since little to no water is required for transporting human excreta, water consumption rates are reduced considerably. For example, UD decreases flushing by as much as 80% (Larsen, Peters, Alder, Eggen, Maurer, & Muncke, 2001). Use of ecological processes to treat residuals also results in less energy and chemical consumption.

Pollution Prevention: Since ecosan systems source-separate human urine and feces before they enter waste streams, they allow for more deliberate processing of these residuals. The diversion of urine alone reduces nutrient loads on WWTF considerably. For treatment plants that lack treatment methods to remove nutrients before discharge, UD can significantly reduce nutrient pollution of open waterways.

Beneficial Residual Products: Source-separation of human excreta significantly facilitates the recapture of nutrient and energy resources they contain. Humans eliminate, on average, about 9 lbs. of nitrogen and almost 1 lb. of phosphorus per year. Urine, which is typically sterile in most humans, contains the vast majority of nutrients concentrated in human excreta (about 80% of nitrogen and about 65% of total phosphorus), and UD can make these nutrients available for reuse efficiently and safely. Worldwide phosphorus sources are being depleted quickly, making the need to recapture this resource in human excreta critical (Mihelcic, Fry, & Shaw, 2011). The World Health Organization (WHO) provides guidelines for the sanitary treatment and reuse of human urine and feces as an agricultural input (WHO, 2006). Additionally, heat and water can be recovered from ecosan residuals, and energy can be produced using biogas digesters.

3.3.3 Limitations and Unknowns

Despite its apparent advantages over conventional sanitation, ecosan system adoption has been slow due to several drawbacks. Perceptions of low public acceptance, regulatory barriers, and persistent unknowns about how to scale-up ecosan schemes can dissuade many populations from pursuing these solutions.

User Receptivity: In general, populations are unfamiliar with ecosan technologies and transitions to ecosan use can be inconvenient or undesirable. Taboos enveloping the subject of human excreta often make the reform of sanitary practices uncomfortable and difficult to discuss publicly. Varying socio-cultural preferences create barriers to ecosan adoption, as do desires to conform to ideals of modernity embodied in the use of water-based flush toilets (Black & Fawcett, 2008). There are mixed reactions to proposals to reuse sanitized human excreta on agricultural crops, especially when awareness of the presence of contaminants of emerging concern (CECs) such as residuals from pharmaceuticals and personal care products (PPCPs) is raised. There is a need for more studies to understand attitudes toward ecosan use in the U.S. (Fewless, Sharvelle, & Roesner, 2011; Lamichhane & Babcock Jr., 2013).

Scalability: It is unclear how successful and efficient ecosan systems are when implemented at large and public scales. New challenges are introduced at larger scales involving storage, transport and processing of large quantities of human urine and feces. Implementation of ecosan systems in densely settled urban environments can be especially problematic since risks for human contact with residuals is heightened and space needed for storage and transfer is not available or is difficult to coordinate (Tilley, 2013). UD systems placed in buildings for public use can fail when users are unfamiliar with UD practices and misuse the installations. Beyond individual installations, regulations do not exist for the easy permitting and oversight of large-scale ecosan projects. Professional capacity to install and maintain these systems is limited in most communities. Low professional familiarity also raises costs for owning and operating these systems.

Greywater: When households and businesses adopt waterless ecosan systems with onsite storage and treatment units, management of other wastewaters produced onsite can become a problem. Many buildings with ecosan systems remain connected to centralized networks for processing grey- and blackwater. Other sites develop their own greywater collection and processing systems, but these arrangements can be difficult to design and regulate. Proposals to scale-up ecosan system use are limited by the questions about how to deal with wastewaters at a larger scale as existing buried pipe networks for greywater and blackwater degrade and require updating.

Lack of Successful Models: A significant challenge posed to ecosan projects is simply the lack of high-profile successful implementations. Especially in the U.S., the absence of large-scale precedents can cast doubt on new proposals and burdens proponents with the need to innovate solutions without contextualized guidance. Without models in place, numerous questions persist about the best ways to regulate projects, to coordinate technical components of the systems, and to successfully market proposals to prospective users. Experimenting with unproven ecosan schemes can be quite unattractive to many communities given the path dependence undergirding dominant sanitation practices and the lack of impressive precedents of community ecosan in place.

3.4 Sanitation Reforms and Ecosan in the U.S.

Due to the residential siting and sometimes informal and unregulated nature of existing ecosan installations, it is difficult to estimate the prevalence of ecosan system use in the U.S (Allen & Conant, 2010). Among the growing body of literature on sustainable sanitation, U.S.-based studies are very few. Yet there are some well-known examples of ecosan systems in the country. Seattle, Washington made international headlines in 2013 when it became home to the world's only six-story composting toilet system, installed at the Bullitt Center, a Living Building Challenge-certified commercial building near the downtown of the city (Nelson, 2013). Average citizens also regularly interface with eco-toilets under less flashy circumstances in public parks where states sometimes have partnerships with companies that maintain rural composting toilets. States with active partnerships include Vermont and Oregon.

Currently, ecosan systems are variably regulated by state in the US. Some states have pre-approved status for eco-toilets that have been certified by NSF or other national and international certification agencies (International Code Council, 2012). At the local level, approval of an ecosan installation can require additional certification and site visits by local public health, plumbing and building code authorities. Overall, state and local regulations for installation of ecosan systems and for processing of the residuals they produce are often unclear and tend towards prohibition rather than encouragement of ecosan system use. Interestingly, no regulations currently exist at national, state or local levels that specifically reference the handling of source-separated anthropogenic urine, which allows for backyard urine recycling practices with no need for oversight (Allen & Conant, 2010).

There have been several impressive advances in sanitation reform and ecosan advocacy in the U.S. recently. Firstly, two programs piloting the community-scale implementation of UD ecosan systems have been pursued in the past five years. These decentralized community projects are the first of their kind in the U.S. and are the focus of the case study section of this thesis. Secondly, a team of U.S.-based ecosan advocates joined together to draft the first international plumbing codes for site-designed composting and UD toilets. The International Association of Plumbing and Mechanical Officials (IAPMO) group, who publishes and markets codes for adoption by regulatory authorities at various scales, commissioned the work. A draft version of these codes is attached as *Appendix A: December 2014 Draft Plumbing Codes for IAPMO*.

Thirdly, non-profit groups across the country have been improving local regulations to allow for easier implementation of ecosan and greywater systems. For example, in Oregon, the non-profit group, ReCode, has been developing cutting-edge performance-based regulations for site-designed ecosan systems. Published as the 2011 Oregon Reach Code for plumbing fixtures, these regulations are framed as semi-experimental 'reach codes' for phased adoption into standard regulations over time, allowing for innovation while also safeguarding the public health. Though the code cannot be reproduced here, a draft copy is available for viewing online at (www.bcd.oregon.gov).The grey literature reports additional sanitation reform activities in pockets of California and the arid Southwest, communities in Oregon and the Pacific Northwest, and in areas across New England. In arid areas, advances have been made in recent years to revise local greywater regulations thereby eroding the barrier that greywater disposal presents for installing ecosan systems, most notably in the states of Arizona, Texas, New Mexico and California (Allen & Conant, 2010).

In addition to these community-based projects, commercial operations have become more aware of inefficiencies in conventional sanitation practices, and are taking advantage of these inefficiencies to create commercial opportunities. An example is found outside of Atlanta, Georgia, where the fertilizer company Ostara has begun to harvest nutrients from sediment deposits in WWTF and pipes. In October 2015, a recovery facility was opened to extract fertilizer nutrients from aging wastewater pipes that have become clogged by buildup of the nutrients produced in human excreta. The plant projects significant earnings from the sale of fertilizer in coming years (Kass A. , 2015). Though ecosan advocates will point out that the best solution is to invest in schemes that source-separate these nutrients before they enter the wastewater stream, this commercial development is interesting and relevant for its indication that perspectives on the efficacy of conventional sanitation methods is shifting and that new practices are needed to improve sanitation schemes overall.

Communities in the U.S. are well underway with experiments to implement ecosan at community-scales, such as in the pilot programs described in the next chapter. According to Winblad & Simpson-Hébert (2004), communal management of ecosan systems introduces advantages that can make these schemes much more accessible to modern-day populations. The experiences of all these advances in recent years suggests that researchers were right in recommending that ecosan advocates focus efforts on smaller-scale, localized implementations of ecosan as the best path toward progress in the U.S. (Fewless, Sharvelle, & Roesner, 2011).

3.5 International Precedents

Ecosan advocates and development agencies have promoted sustainable sanitation practices in countries all over the world in the past few decades. Implementations have includes decentralized rural schemes as well as fairly large centralized systems in urban sites. Of the many worldwide examples of ecosan implementation, the precedents presented here were chosen for characteristics they share with the case studies included in this thesis.

3.5.1 Municipal Leadership in Sweden

Without a doubt, the country that has made the most progress in promoting, researching and installing ecosan systems worldwide is Sweden. It is estimated that there are more than 3,000 UD toilets installed throughout Sweden (Johansson, Jönsson, Höglund, Richert Stintzing, & Rodhe, 2001). Sweden provides examples of both municipal programs and non-governmentally managed projects in various towns (Coalition Clean Baltic, 2009; Johansson & Kvarnström, 2005; Kvarnström, et al., 2006). Despite a backlash against ecosan in Sweden after a period of enthusiastic promotion and adoption, enthusiasm for the approach is resurgent and practices for processing and recycling ecosan residuals are being enhanced (Johansson, Kvarnstrom, & Stintzing, August 2009). Figure 3 shows the town of Tanum in Sweden, comparable to the town of Falmouth, MA, where a municipally-run UD ecosan program has been established.

Figure 3: Coastal Conditions in the Town of Tanum, Sweden. (Kvarnström, et al., 2006)

Topographical and hydrologic conditions of many towns in Sweden are comparable to the conditions of Falmouth. Municipal oversight is also a commonality in these cases.

3.5.2 Non-Governmental Initiatives in Mexico

Mexico is another country that has experienced elevated interest in ecosan technologies over the years. Several initiatives provide examples of non-governmental approaches to disseminating ecosan practices. This approach is analogous to the method of the non-profit REI based in Brattleboro, Vermont. In Mexico City in the late 1980s and early 1990s the non-governmental organization CEDICAR (Center for Capacitation Research) promoted household-based collection and reuse of human urine for growing vegetables in 'kitchen gardens' as a dietary supplement technique among low-income families (Losada, Rivera, Cortes, & Vieyra, 2011). The non-profit work began in 1988 and eventually involved at least 850 families in the Mexico City metropolitan area (Winblad & Simpson-Hébert, 2004).

More recently, a project in Tepotzlán, Morelos, retrofitted about 100 homes with eco-toilets as part of goals to reduce water consumption rates in the arid region. The TepozEco Urban Ecological Sanitation Pilot Project networked support from local and international advocacy and development organizations, as well as some financial support from the local municipality. The program has experienced success to date (Davies-Colley & Smith, 2012).

3.6 Closing

Conventional wastewater sanitation systems have been hailed as marvelous public health inventions, but also as chronic contributors to environmental degradation. With these systems in disrepair throughout the country, U.S. communities are faced with extravagant costs to update these systems, which has pushed some communities to look at alternative sanitation approaches as potential ways to meet local sanitation needs. New developments in the U.S. indicate that interest in improving the efficiency of sanitation practices is on the rise, and community-scale ecosan schemes may have a role in sanitation reforms in the future. Chapter 4 provides extensive detail on the design and implementation of two community–initiated programs to pilot ecosan solutions in New England towns.

CHAPTER 4

COMPARATIVE U.S. CASE STUDIES

4.1 Opening

Chapter four presents comparative case studies of the first two community-scale urine diverting ecosan programs in the country. Detailed description of contextual conditions, the systems' functional components and internal managerial practices of the programs leads into a comparative analysis that identifies common and divergent characteristics of the programs. Chapter five interprets and discusses elements highlighted in this section to identify opportunities, challenges, and strategies for ecosan project implementation in the U.S.

This section methodically details project processes over time to enhance understanding of how these projects have operated in the U.S. context and to provide a potential resource for communities considering large-scale ecosan for their own locality.

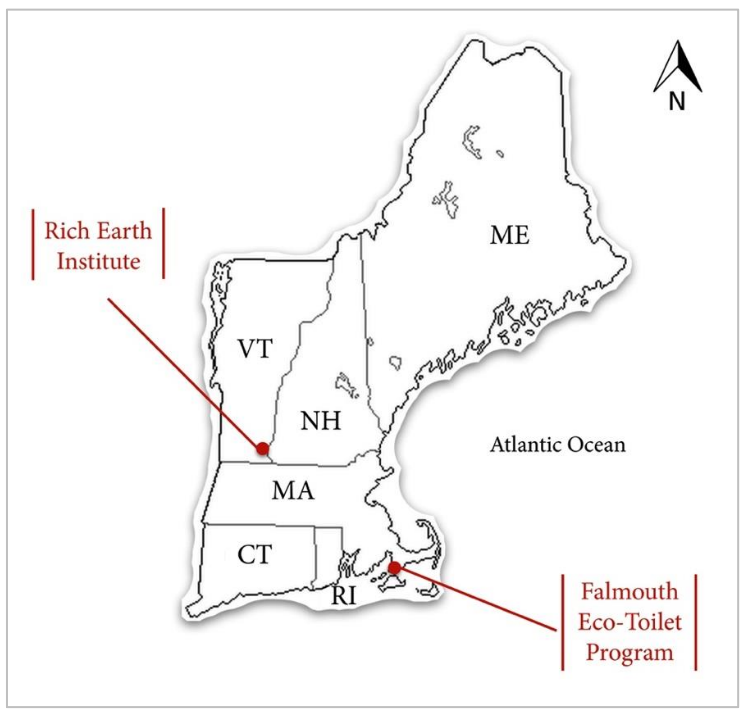

Figure 4: New England Region Indicating Case Study Sites

4.2 Case Studies Design

Documentation of ecosan projects worldwide over the past few decades has generated a considerable body of information. The international ecosan advocacy group, Sustainable Sanitation Alliance (SuSanA), provides a template for executing ecosan case studies and a platform for sharing them online. Almost one hundred studies have been uploaded and can be viewed at the organization's website (SuSanA, 2016) Countless more case studies have been recorded and published in the academic and grey literatures. Despite having access to abundant examples I found it challenging to select parameters most relevant for comparatively documenting the present case studies.

Wishing to document in particular detail the operations and management practices of these programs, I was frustrated to find that these factors are not rigorously recorded in most existing ecosan case studies. In fact, though SuSanA provides a model for the grey literature, there is almost no applied consensus on what factors should be recorded in studies of ecosan projects in the academic literature. Given that managerial factors have been repeatedly, though vaguely, implicated in the overall success of ecosan initiatives (Anand & Apul, 2014; Brands, 2014; Cordova & Knuth, 2005), there is a need to discuss systematic methods for recording these and other characteristics of ecosan projects. To that purpose I offer my case study and design process here as an explanation of my own modest attempt to document the factors that I found to be most influential on the present ecosan projects' development.

The cases are examined across six areas: (1) Project Scope and Goals, (2) Local Geography and Land Uses, (3) Population Demographics, (4) Technical Components of Sanitation Scheme, (5) Program Operations and Management (O&M), and (6) Role of Planners. For documenting technical schemes, I referred to a report by E. Tilley (2013) that provides a framework for describing the technical components of decentralized onsite sanitation systems. Tilley outlines five functional groups of sanitation systems processing: (1) User Interface, (2) Collection and Storage, (3) Conveyance, (4) Treatment, and (5) Use and Disposal. Other areas of focus studied here, such as project scope and local socio-cultural and physical conditions, are commonly recorded in ecosan case studies.

In addition to these characteristics I have incorporated elements not commonly explored in the literature. I apply a land-use analysis to test a hypothesis put forth in several recent studies suggesting that ecosan projects, particularly those with a urine diversion component, occur and succeed more in proximity to agricultural and open space uses where markets for urine-based fertilizers can develop (Anand & Apul, 2014; Fewless, Sharvelle, & Roesner, 2011). The demographics analysis applied and discussed in the remainder of the thesis is more critical than typical population descriptions since I find that fairly narrow demographic groups are currently drawn to ecosan solutions in the U.S. I argue that this trend and its potential implications should be studied further. This thesis also inquires into how professional planners have interacted with the projects, and what impacts the profession has had on them to date, if any.

Finally, development of an O&M practices analysis required significant revisions over time, especially given the lack of precedents with this analysis. I concluded to consider project decisions and practices across seven categories: (1) Project Initiation, (2) Community Base, (3) Formalization, (4) Funding, (5) Public Education and Participant Relations, (6) Regulations, and (7) Research. Other studies of ecosan programs typically document funding mechanisms and regulatory procedures, but they are not usually considered facets of program O&M. I intentionally place these subjects under the O&M umbrella to emphasize my finding that the regulatory and financial processes that ecosan pilot projects experience in the U.S. are currently so unfamiliar and complex that individual programs have a degree of freedom to choose or even design funding and regulatory pathways strategically according to their goals and prospects.

As the reader will see, a majority of the parameters used to characterize the projects shed light on their differing conditions and decisions more than commonalities. Though I do not wish to overstate the differences between the programs, it is my hope to understand and explain links between specific local conditions and strategies and how these factors have impacted the programs' trajectories over time to create quite distinct enterprises. Brief summaries of each program are provided below in Figures 5 and 10.

4.3 Rich Earth Institute – Brattleboro, Vermont

4.3.1 Introduction: 'Peecycling' for 'Fertilizer from Urine'

The REI project arose in 2011 as the initiative of two individuals interested in promoting ecosan awareness and adoption in the U.S. The appeal of UD and ecosan for the Brattleboro community did not result from any imminent need, but rather as a proactive, community-based sanitation reform movement. In Brattleboro, sewers and a WWTF serve the downtown area and much of the surrounding suburban settlement. The municipal WWTF was originally built in the second half of the 1960s, and was upgraded in the early 1980s to incorporate secondary treatment technologies. A WWTF update completed in 2013 incorporated advanced tertiary

Figure 5: REI Project Overview

Location: Brattleboro, VT
Period: 2011 to present
Goals: Recycle urine as fertilizer; perform experimental field trials; promote ecosan awareness in U.S.
Scope: Over 150 participants have donated at least 10,000 gallons of urine in 5 years
Management: Non-profit oversight and administration
Partnerships: Local septic business, family farms, research institutions and universities, local WWTP
Regulation: Series of state permits that have evolved over time to allow for treatment and disposal of urine; currently REI has a state permit for a treatment process that produces sanitary urine fertilizer for unregulated application in VT
Collection: Varied, low-cost, adaptable options ranging from handheld devices to commercially manufactured eco-toilets
Transport: Septic hauler
Treatment: Pasteurization of urine; previous methods included time and temperature storage

treatment facilities into the plant's wastewater remediation process and cost the town a total of $22,500,000 (Brattleboro DPW). This expensive update obligated many Brattleboro residents to consider the costs of municipal wastewater treatment. Rural areas of Brattleboro are served by decentralized, private septic tank systems. Photos related to project activities are attached as *Appendix B*.

4.3.2 Project Scope and Goals

In 2011, two citizens of Brattleboro, VT founded REI with the organizational mission to "advance and promote the use of human waste as a resource." Soon the organization identified several central goals for its work: to perform research field trials on the use of human urine as a fertilizer in the U.S.; to coordinate a community-scale urine collection and recycling scheme; and to network itself with similar groups and individuals nationally and internationally to promote ecosan awareness and adoption in the U.S.

Since 2012 REI's Urine Nutrient Reclamation Program (UNRP) has organized at least 150 individual volunteers to divert and donate their urine to REI for sanitary treatment and application as a fertilizer in the state. To date, more than 10,000 gallons of human urine have been donated and reused as a fertilizer on two family farms near Brattleboro. Additional goals have included public education and advocacy for ecosan, lowering household water consumption by reducing flushing, mitigating sewage flows and nutrient inputs into Brattleboro's WWTF, and the execution of a series of research projects. Research topics have involved hay cultivation with various concentrations of urine-based fertilizer, trialing of several sanitization methods, urine fertilization of human food crops, volume reduction of stored urine, and the fate of PPCP's in agricultural soils (REI, 2016). The scope and goals of REI

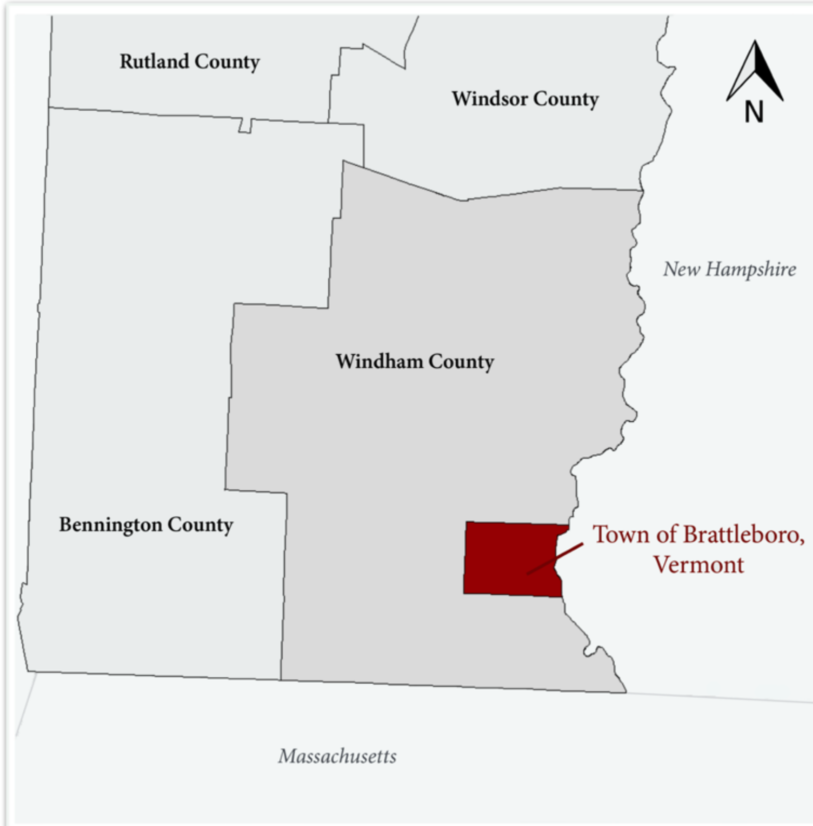

Figure 6: Context Map for Brattleboro, Southern Vermont

have been broad and somewhat malleable, allowing the group to collaborate with a wide range of groups and research institutions.

4.3.3 Local Geography and Land Uses

Brattleboro, Vermont is a town in rural Windham County of southeast Vermont (Figure 6). The town is characterized by a small, densely settled downtown area surrounded by some suburban development and then vast expanses of agricultural lands, wooded areas, and green open space. The Connecticut River and the state of New Hampshire border Brattleboro along its east side, and the Massachusetts state line to the south is a short drive from the town. Brattleboro has a total area of 32 square miles, and about12,046 residents. Population density is quite low, at only about 376 persons per square mile (U.S. Census Bureau, 2009-2013; U.S. Census Bureau, 2010).

Brattleboro experiences cold, snowy winters and mild summers. Average temperatures range from lows averaging 33.7 degrees Fahrenheit in winter months, to highs averaging 65.9 degrees Fahrenheit in the temperate summers. On average the town receives about 51 inches of precipitation yearly (Graphiq, Inc., 2016). Elevation is 240 feet above sea level (Webmont, Inc., 2016).

As shown in Figure 7, the most abundant land use in Brattleboro is Open and Green Space, which groups undeveloped uses such as forested areas, wetlands, and public open space. Developed areas are concentrated in commercial and residential areas of the downtown, limiting sprawl. Low incidence of surface water significantly reduces concerns over contaminating waters through urine fertilizer applications.

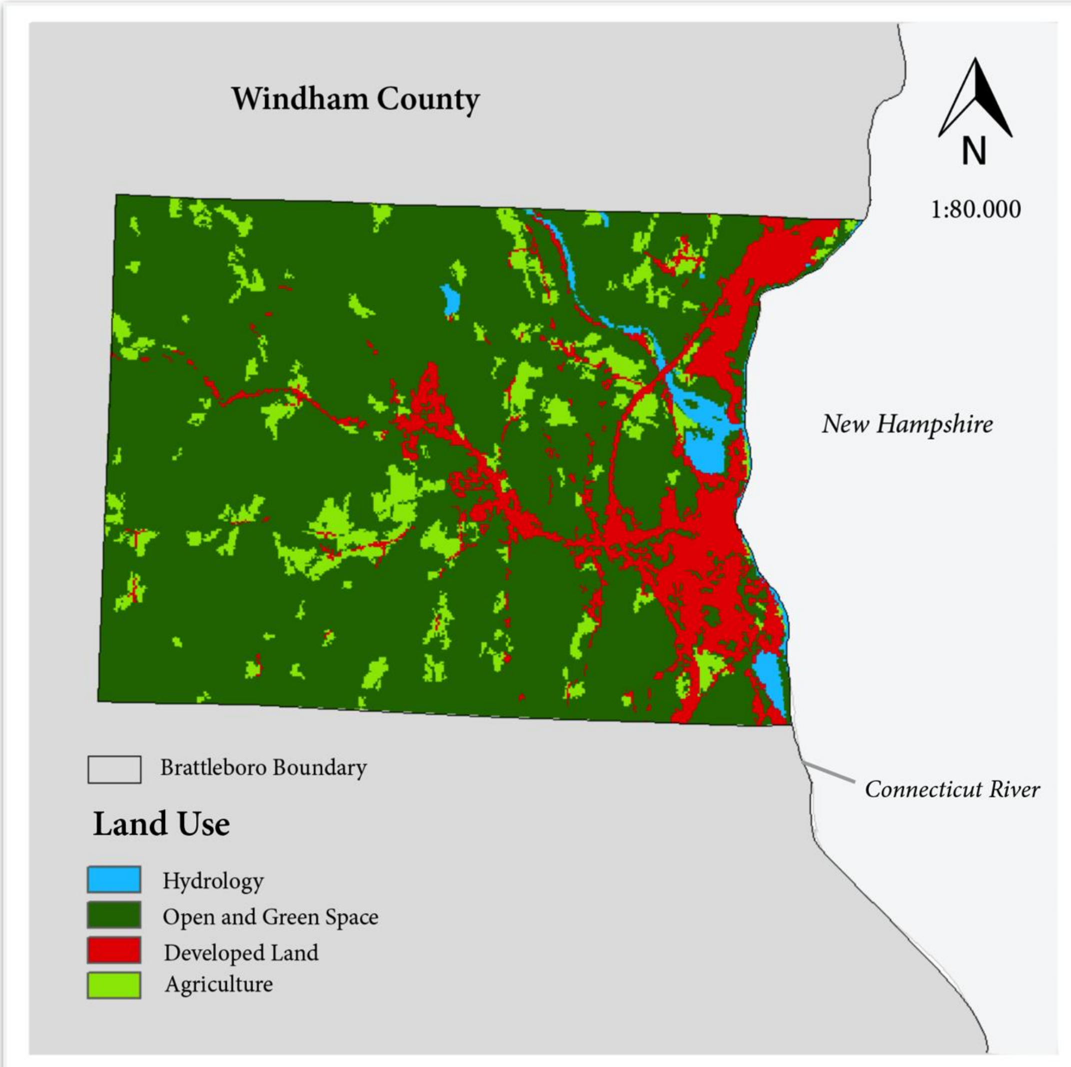

Figure 7: Land Uses in Brattleboro, Vermont

The prevalence of agricultural activities in the area and a general 'green' identity of the state of Vermont have contributed to a Brattleboro culture that values low environmental impact living, recycling and composting, renewable energy use, and sustainability- and food-based activities such as home gardening, attending local farmers markets, and supporting vibrant regional fairs and a cooperative grocery store and community center. World Learning, an internationally renowned, sustainability-focused graduate school is located nearby and a number of students remain in the area following graduation, further contributing to a ‘green’, internationally-oriented, and communal culture in the town.

The resulting local appreciation of agriculture-oriented sustainability has shaped the motivations and operations of REI considerably. As evidenced by REI’s slogan, *Fertilizer From Urine: Clean Rivers. Sustainable Farms*, the agricultural application of nutrients has been central to the organization’s mission and activities since its outset. Complementary interests in nutrient pollution reduction, lower water consumption rates, and reduced infrastructure and energy loads on the municipal WWTF have certainly influenced REI’s undertakings, but agricultural motivations have remained the organization’s main focus for the UNRP and other endeavors. It was also this focus on agricultural application that led REI to strategically choose UD and community-scale ‘peecycling’ as their first and flagship project.

4.3.4 Population Demographics

An average citizen among Brattleboro’s 12,046 residents is white, entering middle age, earns low-to-middle income per household, and is highly educated. Table 1 below summarizes demographic data for the town.

Table 1: Brattleboro Demographics

		Brattleboro	U.S.
Population	Total #	12,046	--
Density	Persons/sq. mile	376.4	--
Households	Total #	5,562	--
Age	Median age	44.7	37.3
Race	% White	92.1	74.0
Income	Median HH Income	$45,119	$53,046
	% Pop under Poverty Level	16.2	15.4
Education	% Pop over 25 with bachelor or graduate degree	34.4	28.8

Source: (U.S. Census Bureau, ACS 2009-2013; U.S. Census Bureau, 2010 Census)

Relative to the national median, Brattleboro's population is aging, with a median age of 45 years old. Brattleboro is racially much whiter than other parts of the country, with more than 92% of the population identifying as white. Educational attainment of a college or graduate degree is 5% higher than the national average. Despite slightly higher educational levels overall, median household income levels are almost $8,000 less than the national median, and the poverty level is elevated.

General population statistics describe Brattleboro as a whole and not program participants specifically. Comprehensive data gathering on the participants in the UNRP fell outside of the scope of this thesis, but should be pursued in the future for the valuable findings it could reveal about characteristics of individuals drawn to community ecosan. The summary given here instead indicates demographic characteristics prevalent in a community where an ecosan project has arisen and been generally accepted.

4.3.5 Technical Components of Sanitation Scheme

Through its UNRP initiative, REI has coordinated a comprehensive decentralized UD sanitation scheme from collection to treatment and disposal. Details on each component are given below, and full components of the REI sanitation system are summarized graphically in Figure 8.

User Interface: In the REI project, mechanisms for urine collection have been designed, diversified and adapted over time to meet UNRP participants' needs and feedback. User interface devices for residential collection of urine include three low-cost options: (1) a handheld collection device, which can be as simple as a recycled yogurt container; (2) a stand-alone funnel urinal attached to a five-gallon container; and (3) a UD toilet insert, such as those manufactured by the Separett company or a 'nun's cap' insert such as those commonly used in hospitals and nursing homes.

For urine collection at public sites, an additional user interface was developed. Urine-only UD porta-potties owned and managed by project partner, *Best Septic* company of Westminster, VT, can be rented for public events such as outdoor fairs or weddings. REI has used them at many of their own public events to collect urine for use in research requiring a sample from the general public.

Collection & Storage: UNRP participants convey diverted urine captured with a user interface device through tubing or by direct pouring into one of a series of storage units. Feces is sometimes similarly diverted to a storage receptacle for processing independent of the program, or is disposed of via conventional wastewater system by flush toilet.

Onsite storage units located at participant residences store urine in the short term. Three choices of receptacle are used for this onsite storage: (1) a five gallon container, (2) a fifty gallon drum, and (3) a 275 gallon tank. Long-term, centralized storage sites are located at a Drop-Off Depot near downtown Brattleboro and at participating farms. Generally, urine donor participants with 5 gallon containers for residential storage rely on the centralized depot for regular emptying of their containers. An automated pump, designed to engage when the nozzle is lowered into a urine container, facilitates collection at the depot. The pump transfers urine into 275 gallon tanks for long-term storage.

Conveyance: There are two levels of conveyance in the UNRP initiative. The first is decentralized, wherein individual participants convey their urine to centralized depots, and the second is large-scale transportation of sizable quantities of urine performed by a contracted septic hauler. Urine donors typically realize small-scale transfer of their urine to a drop-off depot in five-gallon containers by their own motor vehicle or by bike delivery. As previously stated, the depot is equipped with an automated, self-service electric pump to transfer urine from 5-gallon containers to large holding tanks so that risk of contact or spills is virtually eliminated.

Project partner *Best Septic* performs large-scale, centralized transport of urine by pumping larger storage tanks at depots and residences regularly. Several households have installed their own 50 gallon drum or 275 gallon tank for *Best Septic* to pump directly from the residence. Urine is conveyed by septic truck to sites for long-term storage and processing. *Best Septic* has added a urine-only tank to their septic truck for this purpose.

Treatment: Initially, both pasteurization and time and temperature treatments were used to sanitize the urine prior to agricultural application. Modifications in project regulation in the past two years of the UNRP have given preference to pasteurization as a treatment method. REI has designed and built a mobile pasteurizer for this purpose. Urine treated with the mobile pasteurizer is considered sanitary fertilizer approved for unregulated application in the state of Vermont.

In the last year, REI has begun experimenting with reverse osmosis processes to additionally treat urine by reducing its volume. REI has adapted a reverse osmosis machine to extract water from urine, concentrating its nutrient resources and reducing its volume significantly. REI is continuing to trial additional methods to treat urine for pathogens, volume reduction, and odor mitigation.

Use & Disposal: REI has realized both small-scale and large-scale applications of sanitized urine for fertilization and for experimental research. A small hand-wand can be used for localized applications, and a custom-built applicator has been built and used for large-scale hay field fertilization. The disposal methods of the UNRP have been framed as research-centered resource reuse since the program's inception. This approach has helped garner enthusiasm and support for its progress at local, national, and international levels.

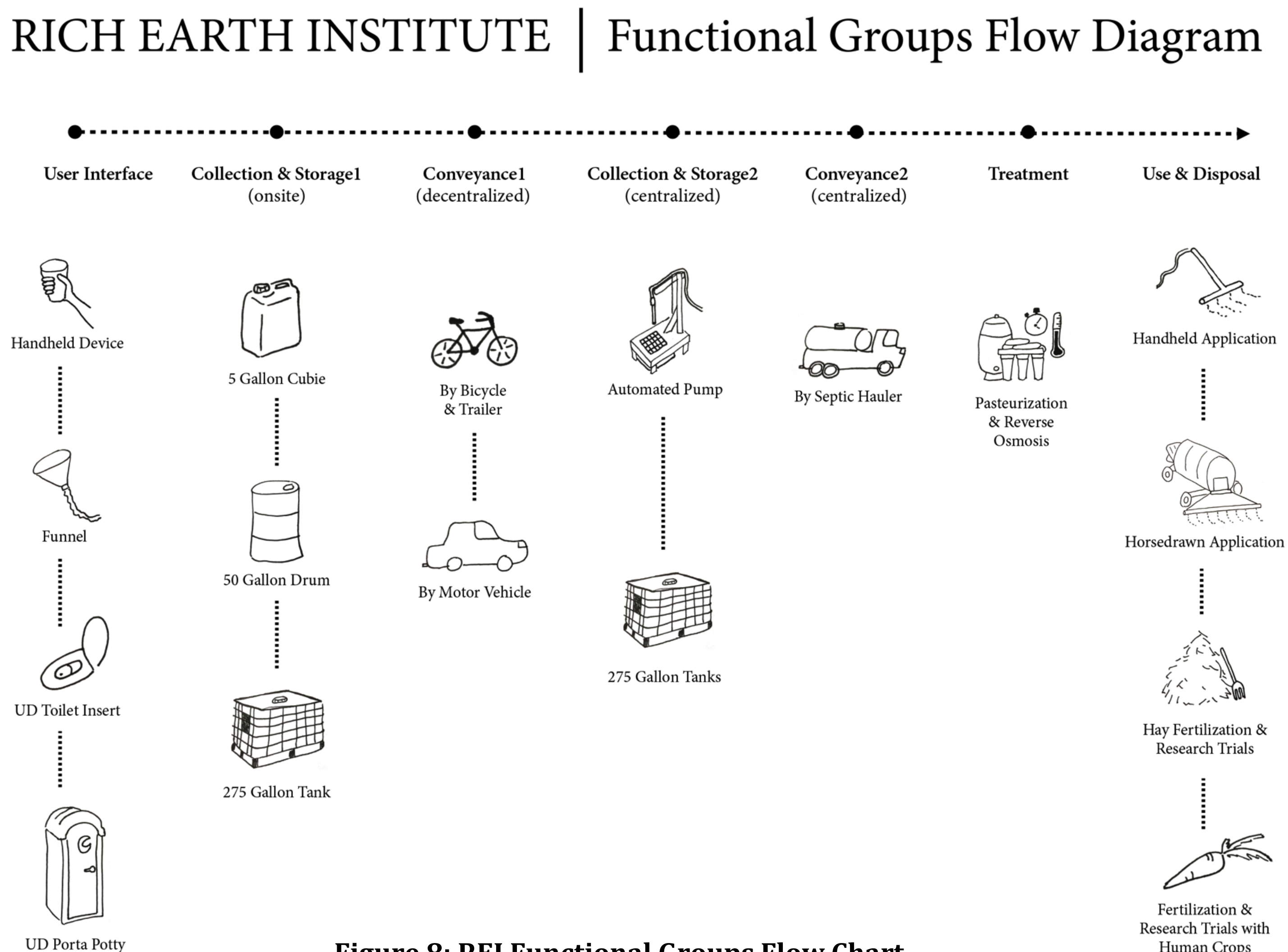

Figure 8: REI Functional Groups Flow Chart

4.3.6 Program Operation and Management

O&M aspects of REI's programming can be described as proactive, personal, comprehensive, strategic, and community-based. Specific aspects are reviewed below.

Project Initiation: Evaluate and Act

The REI project was initiated out of the founders' personal interest in the subject of composting toilet use and human nutrient cycling. An expensive update to Brattleboro's WWTF prompted town-wide reflection on the costs of conventional wastewater systems previous to the update's completion in 2013. Motivated by general sustainability-based values for water conservation, energy and materials savings, and nutrient reclamation benefits offered by ecosan systems, two residents of the area decided to form an organization to promote sustainable sanitation approaches.

Rather than identify a single motivating problem in the community as a justification for the project, the founders adopted a multifaceted, holistic systems critique to explain the relative benefits of community-wide ecosan sanitation systems. After evaluating several avenues for action, the founders chose community-wide UD, or 'peecycling,' as a first project due to its high acceptability relative to work involving human feces, its low costs of implementation, its high efficacy in reducing nutrient loads in wastewater; and its deliverance of a fertilizer end product for local use.

Community Base: Charismatic Leaders and 'Green Citizens': Almost immediately, outreach to a broad spectrum of actors in the community of Brattleboro and neighboring counties and states began. The two co-founders' established prominence and positive reputations in the local area facilitated this outreach: one as a recognized expert in ecosan system design and implementation, and another as a well-known and successful administrator with strong experience as a school principal in the community. The influence of personal magnitude of the co-founders is evident in this anonymous feedback from a urine donor: "I continue to be very positively impressed with the intelligence, creativity, energy, and scientific methodology present among the leaders of this project" (Rich Earth Institute, 2012). Another respondent, when asked about their motivation to participate in the project, simply stated, "[The founder] is a friend" (Rich Earth Institute, 2013).

Additionally, a strong 'green' identity commonly shared by residents of Vermont explains a high incidence of early adopters of sustainable practices in the area. This identity phenomenon has been referred to as 'green citizenship' and is the subject of political scientist Andy Scerri's book, *Greening Citizenship: Sustainable Development, the State and Ideology* (2012). Scerri argues that 'green citizens' represent a fairly new socio-cultural group in the U.S. whose individuals share a degree of affluence (education and social security) and increasingly dedicate their attention to environmental justice and local governance pursuits. More is said on the subject of 'green citizenship' and its relevance to ecosan adoption in Chapter 5.

The appeal of 'peecycling' has been strong among such citizens, who, along with other shared qualities, typically have high levels of formal education. This last quality has proven key to participant appeal since urine donors have been highly curious about and motivated by the promise of generating scientific results through REI's trial experiments. More is said about this aspect of the project under the *Research* section below.

Recruitment of targeted actors went beyond broad social base building. Direct recruitment of key actors in desired sectors has been highly strategic, and it has targeted individuals and groups with various assets: social and political influence in the community, financial wealth or access to monetary networks, experience with start-ups and non-profit management, marketing and public relations, and specialized knowledge in relevant subjects such as wastewater treatment and engineering, ecosan implementation, green building, construction experience or materials access, agricultural knowledge, and relations with academic or community institutions that could be levered to advance the work of REI. REI often asks targeted actors to become board members or engages them regularly to keep them aware of REI's activities and to invite them to be engaged and supportive of the project rather than distant and adversarial. Key partnerships include the formal contractual relationship with local *Best Septic* company that collects and transports urine for REI, the Brattleboro WWTF that has stored urine indoors for the project during cold winter months, and state environmental regulators who have worked diligently with REI to oversee and permit the institution's activities.

Formalization: Non-Profit: In order to obtain funds and formal recognition for the activities of the institute, REI decided to seek status as a 501(c)(3) non-profit organization in 2012. This formalization pathway was seen as a way to allow the group to solicit donations and grants to focus on research, development, and advocacy activities, as opposed to for-profit ventures. There was some debate about whether or not non-profit status was the best choice for REI during the first months of the organization's development. The extensive experience that many advisory members had with administrating or participating in non-profit organizations made this option most appealing for the autonomy it would grant REI. Sentiments against a commercialization-based, or for-profit organizational model played a significant role in the decision on how to formalize the group's activities. This decision has been revisited in recent years since grant- and donation-based funding has not yet been sufficient to stabilize yearly project budgets.

Funding: Public & Private Grants and Donations: To solicit private donations, REI has pursued broad fundraising campaigns involving personal letter writing, in-person visits, and solicitation at public events. Over time, donations have supported a consistent fraction of REI's operation costs. Simultaneously, REI has applied for grants with both state and private groups. REI has received Sustainable Agriculture Research and Education (SARE) grants administered by the U.S. Department of Agriculture (USDA) every year to support specific research projects. They have also participated in group research grant proposals to the Water Environment Research Foundation (WERF), a non-profit research organization in the U.S. These grants have provided more significant funds to sustain administrative as well as operational costs. REI has received some smaller grants to date as well.

To receive incoming funds previous to formalization as its own non-profit organization, REI established a proxy relationship with an established non-profit to process their payments in exchange for a small fee. While supporting its own activities in these ways, REI has generated income opportunities for other groups in the area. For example, REI pays project partner, *Best Septic*, tipping fees for transportation of urine for the project. UD porta-potties developed by *Best Septic* are now successfully rented to the general public, generating a new source of income for the company. Discussions with a local composting facility have entertained the idea of producing a solid urine fertilizer product for general sale, though no projects have been implemented to date. To date REI's relationships with local family farms that receive urine fertilizer applications have not involved monetary exchanges. In effect REI gifts free fertilizer to the farms.

Public Education & Participant Relations: Dialogue & Involvement: As an initial step in public education programming and promotion of the UNRP initiative, REI founders installed and maintain a fully functioning UD toilet demonstration site at REI headquarters in downtown Brattleboro. The site consists of a urine-diverting dry toilet (UDDT) model manufactured by Full Circle Composting Toilets®. Individuals and groups are received at the site for a tour of the demonstration toilet system. REI Administrative Director Kim Nace estimates that during the summer months of the first year of the project, she gave tours of the demonstration toilet on a nearly daily basis (Nace, personal communication, 2015). General education efforts of REI have focused on various topics related to conventional and ecological sanitation practices. Information has been made available through a website developed by REI, through public displays and workshops, and through private presentations and conversations.

Recruitment of volunteer participants, or "urine donors," began through informal personal invitations from REI founders and board members. The community of participants was recorded more formally when an email and newsletter directory was established to regularly notify donors of events, developments, and results of the project. Recruitment efforts have expanded over time to include public outreach at events such as the Strolling of the Heifers event in Brattleboro, Urine Donor Kick-Off receptions with free food and entertainment, and targeted invitations to individuals and groups for informational presentations and conversations at REI headquarters.

Regular communications with urine donors through email, public events and open houses hosted at the headquarters of REI have made participants feel deeply involved in the day-to-day processes of the project. To incentivize collection efforts, prospective participants are often offered free or low-cost collection accessories prepared by REI to ease the adoption of residential urine collection. A friendly competition to track individuals who donate the most urine to the UNRP, known as the annual 'Piss-Off', is organized to recognize and applaud project participants.

Regulations: State Environmental Permits for Non-Profit: No federal or state regulations in the U.S. currently reference the diversion, storage, treatment or beneficial use of human urine specifically. Aware of this gap in regulations, the co-founders of REI have taken a proactive approach with state regulators to co-design regulations for the UNRP. Phone and email exchanges, in-person visits, and formal presentations with a group of environmental regulators at Vermont's Agency of Natural Resources (ANR) over the past several years have encouraged personal familiarity among project leaders and regulators, demonstrated REI's scientific and technical expertise, and have opened doors for REI to share its own views on how to best regulate their activities in the state.

REI representatives have advocated for performance-based regulation of their activities as opposed to technology-based regulation. In other words, rather than requiring that a certain technological process, such as pasteurization, be used to treat anthropogenic urine, performance-based regulations would require that certain targets for biologic and chemical contaminant remediation be met by any of a number of treatment processes. This approach meets public safety goals while also allowing a group like REI to identify a range of treatment regimens that comply with sanitation requirements. A performance-based approach to sanitation regulations contrasts with historical technology-based regulation of conventional WWTFs in the U.S., where primary, secondary and tertiary treatment technologies have been adopted over time to comply with federal health mandates (Melosi, 2008).

Initial regulation of REI's activities followed this performance-based approach, as both pasteurization and time-and-temperature treatment processes were allowed as long as they demonstrated human pathogen remediation through sample testing. Since 2015, however, regulations shifted to require that REI obtain ten-year certification as a solid waste management facility. This approach has required the permitting of REI's mobile urine pasteurizer as a designated treatment facility in the state. The new regulation has limited treatment to pasteurization, but is advantageous in other ways. According to the new rules, urine pasteurized by REI may be applied freely anywhere in the state just like any other commercial fertilizer compound, whereas previous permits required that specific urine application sites be approved before fertilization. Current regulations also make it easier for REI to market a urine-based fertilizer product in the state.

Research: Community Scholarship & Knowledge Share: The generation of U.S.-based data on UD and ecosan processes has been a central goal of the REI project. REI began performing experimental field trials with anthropogenic urine as a fertilizer in their first year of operation. The number and nature of the institute's experiments have expanded every year since 2012. Research has focused on numerous topics, including identifying ideal application rates of urine, assessing the viability of various treatment regimens, and understanding the fate of pharmaceuticals and other PPCPs after urine is applied to soils and to human food crops.

The impressive scope and rigor of scientific experiments REI has realized have been possible due to unique scholarly assets in the community. Locals often refer to REI co-founder, Abe Noé-Hays, as a self-trained genius. As an inventor and scientist, Noé-Hays studied, designed, and marketed original ecosan systems independently for many years previous to founding REI. His profound knowledge of ecosan technical and regulatory systems has made the innovative work of REI possible. Noé-Hays' scholarship has combined with the knowledge of other locals to form a capable, community-based alliance with expertise that spans the following areas: wastewater engineering, green building design, composting toilet installation, septic management, microbiology, graphic design, administration, agricultural systems, and more.

In addition, a critical component of REI's research has been to return data generated by experiments back to volunteer urine donors who support the UNRP. The return of information to participants has, in turn, invigorated engagement in the project and helped motivate participants to accept the inconveniences associated with domestic urine collection. Prospective participants in the project are often invited jovially to 'do science' with REI, and one participant explained that "being part of a cutting edge study" has been a main motivator for their involvement with REI (Rich Earth Institute, 2013).

4.3.7 Role of Planners

The role of professional planners in the work of REI has been as supportive, though somewhat distant, observers. The entire Windham County Planning Commission was invited to REI headquarters early on in the project to tour the demonstration UD toilet system and to view a presentation on REI's research activities. The commission's reactions to the presentation were positive, though no further actions developed from the meeting. Since REI has dealt directly with the state ANR to regulate their activities, the town's planning department has had no formal regulatory input to the project to date.

4.4 Falmouth Eco-Toilet Demonstration Program – Falmouth, Massachusetts

4.4.1 Introduction: Eco-Toilets as an 'Alternative to Sewers'

The proposal to trial eco-toilets in Falmouth, MA as a potential 'alternative to sewers' arose in a context of environmental crisis. By 2010, increasingly ruinous levels of nutrient pollution in the coastal ponds and estuaries of Cape Cod were pushing local towns to choose among costly solutions to the problem. Lawsuits brought against the EPA by a prominent New England law firm for the agency's inadequate regulation of Clean Water Act statutes in the area further accelerated concerns and mandatory water quality planning processes across the Cape (Cape Cod Commission, 2013; Cassidy, 2010). For more details on this regulatory and planning context, see Figure 9.

Figure 9: The Falmouth CWMP and the CCC Section 208 Update

In 2007 Falmouth began a Comprehensive Wastewater Management Plan (CWMP) process as a municipal planning obligation required of all Cape Cod towns. Town CWMPs are submitted to the Cape Cod Commission (CCC) for review and to MassDEP for approval. Due to this arrangement, the CCC has had direct input on Falmouth's CWMP.

In 2010 and 2011 environmental lawsuits filed against the EPA over Cape Cod nitrogen pollution placed pressure on Falmouth and other towns to accelerate their CWMP processes. Falmouth's CWMP was completed in September 2013 and included a series of approaches to immediately address nitrogen pollution in the area. The Eco-Toilet Demonstration Project discussed here is just one of several strategies outlined in the 2013 CWMP to control wastewater pollution in its coastal waters.

Under pressure from the federal EPA, in January 2013 MassDEP ordered the CCC to update its Section 208 Plan for water quality management on Cape Cod. This update was completed in June 2015. This broader regulatory and planning context shows that Falmouth's municipal CWMP process is one piece of a larger regional planning process to mitigate wastewater pollution in the Cape Cod region.

In the town of Falmouth, a proposal to address the town's nutrient pollution problem by installing a municipal sewer system was voted down in 2009 due to its steep price tag of $600 million (Gentile, 2014). Still needing to identify remediation strategies for the town's Comprehensive Wastewater Management Plan (CWMP), a group of locals proposed the community-wide installation of UD eco-toilets to directly address the 80% of nitrogen pollution entering coastal waters directly from residential septic tanks (Cape Cod Commission, 2015). In May 2011 Falmouth citizens voted to fund a pilot demonstration project with eco-toilets in one watershed of the town.

Currently, sewers serve just 4% of developed areas in Falmouth. The single municipal WWTF in Falmouth was built in the 1980s and received an update completed in 2005. This update incorporated nutrient remediation works and cost the town $15,000,000. Remaining developed areas are mostly served by septic systems and cesspools, which like septic systems require pumping every three years by a licensed professional (Falmouth Wastewater Department, 2013). Photos related to Falmouth program activities are attached in *Appendix C*.

4.4.2 Project Scope and Goals

The Falmouth Eco-Toilet Demonstration Program, established in 2011, has the broad goal to "establish a basis in fact for use of eco-toilets in Falmouth's Comprehensive Wastewater Management Plan" (CWMP) (Falmouth WQMC, 2012). More specific goals include evaluating UD as a viable nutrient pollution reduction strategy, assessing community receptivity to residential eco-toilet use, and improving understanding of financial and regulatory barriers to adopting eco-toilets. Though originally intended to involve up to 50 participating households, only about 10 households were confirmed to have joined the program by its registration deadline, Oct 31, 2014 (Driscoll S. F., 2014).

Participating families were able to choose from among 10 pre-approved, commercially manufactured eco-toilet models for installation in their homes. In order to receive financial incentives of the program, participants agreed to a one-year monitoring program to track nitrogen levels in their septic tanks.

A specific research study was designed to determine whether urine-diverting eco-toilet systems lowered nitrogen inputs to septic tanks. The eco-toilet approach is being evaluated alongside other innovative techniques to mitigate nutrient pollution of coastal waters through the town's CWMP, whose design has been reviewed by the Cape's

Figure 10: Falmouth Project Overview

Location: Falmouth, Cape Cod, MA
Period: 2011 to present
Goals: Evaluate urine diversion as a viable nutrient pollution reduction strategy; test user receptivity; produce data for cost/benefit analysis of ecosan
Scope: Between 10 and 15 households
Management: Municipal oversight and administrated by contracted private company
Partnerships: County public health board, environmental non-profit organization, regional planning commission
Regulation: Individual residences permitted for installation of eco-toilet; special approval of urine diverting eco-toilet models by state plumbing board
Collection: Commercially available eco-toilets, some with UD
Transport: No centralized transport; individual households responsible
Treatment: No centralized treatment or disposal processes arranged; individual households responsible

regional planning authority, the Cape Cod Commission (CCC).

4.4.3 Local Geography and Land Uses

The town of Falmouth is located on a water-bounded cape of Massachusetts. Almost entirely surrounded by water bodies and with an elevation near sea level, Falmouth has been driven to pursue the Eco-Toilet Demonstration Project by complications arising from its hydrologic conditions (Figure 11). The other fourteen towns that comprise Barnstable County have also struggled to manage discharges of anthropogenic nutrients from septic tanks into the coastal waters of Cape Cod. Yet Falmouth's fifteen estuaries comprise a full third of all estuaries on the Cape, making remediation plans there particularly important for the entire region (Teehan, 2013).

The Eco-Toilet Demonstration Program is being implemented in the Little Pond watershed, home to the most degraded estuary in the town. Figure 11 indicates the locations of the Little Pond watershed and the *Green Center Inc.* non-profit group in Falmouth, as well as the Barnstable County Department of Health and Environment (BCDHE) to the northeast of Falmouth. Falmouth encompasses the two historic villages of Hatchville and Waquoit.

Falmouth's climate is tempered by its coastal conditions. Average temperatures range from a winter average of 41.6 degrees Fahrenheit, and summer temperatures average 66.2 degrees Fahrenheit. The town receives about 45 inches of precipitation yearly (Graphiq, Inc., 2016). Falmouth's coastal elevation is quite low, and the water table is high.

Figure 11: Context Map for Falmouth Eco-Toilet Program

Falmouth's land use map (Figure 12) reveals at a glance the prevalence and importance of surface water in the municipality. Little total area is dedicated to agricultural land uses, and much of what exists is occupied exclusively for cranberry bogs. Compared to the town of Brattleboro, Falmouth's 44.1 square miles is relatively densely settled with about 715 residents per square mile (U.S. Census

Bureau, 2010). Much of the town's area has been developed, and this development is sprawled along the town's traffic corridors and waterfront areas.

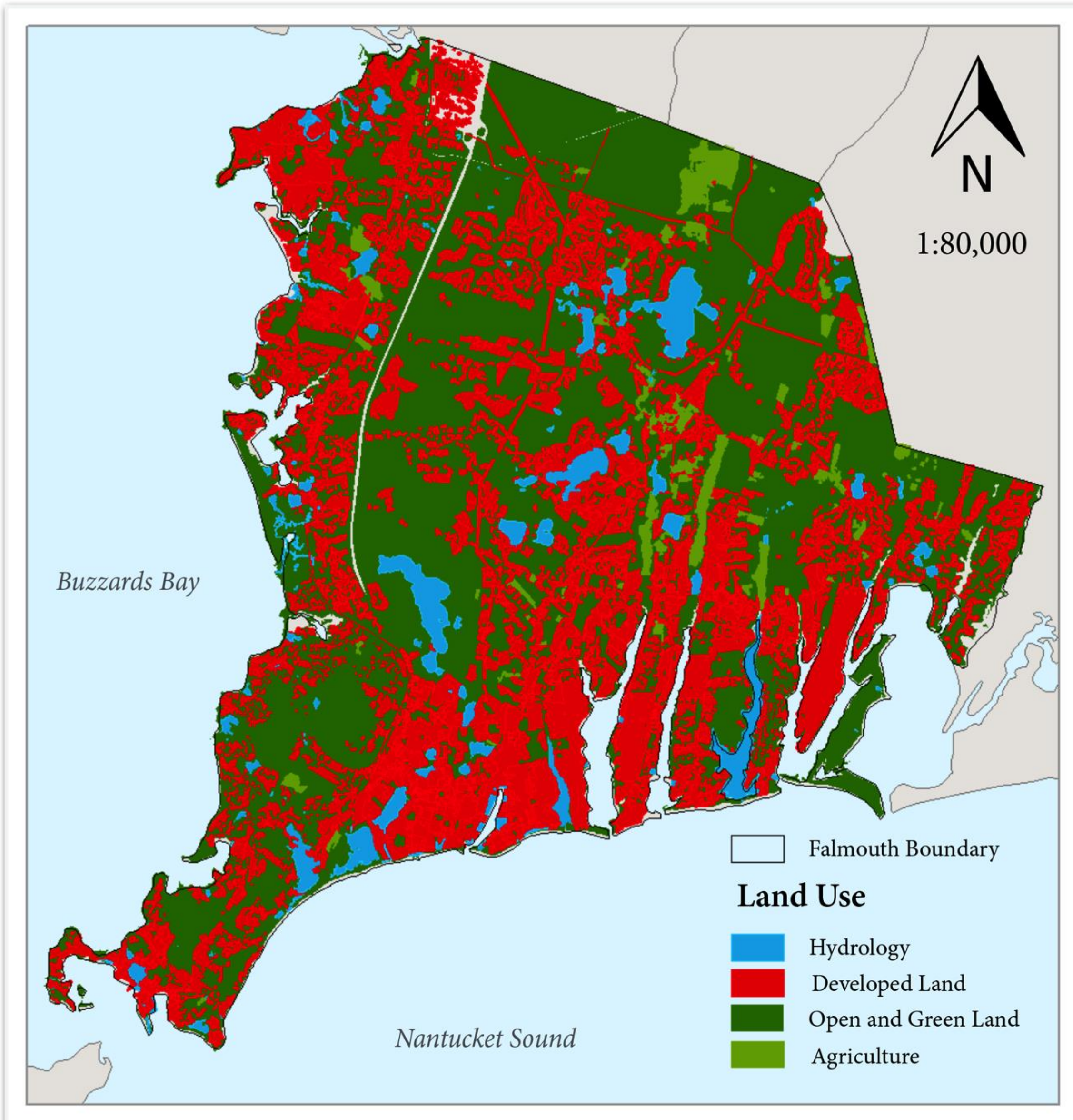

Figure 12: Land Uses in Falmouth, Cape Cod, Massachusetts

Falmouth's land-use arrangements explain much about the motivations and design of the town's Eco-Toilet program. The main motivator for seeking sanitary solutions has been consideration of water pollution and environmental protection. Little attention has been dedicated to residual reuse in the project, and this reflects the land-use realities of the coastal town. Not only is a small portion of the town actively employed in agricultural activities, but also the immediate concern over nutrient abatement along the coast has countered interest in producing a fertilizer product for local application. Political efforts are already underway to limit commercial fertilizer consumption for landscaping and other uses in towns across the Cape (Milton, 2011).

4.4.4 Population Demographics

Falmouth's population of 31,531 is aging, financially secure, highly educated, and predominantly white. Demographic data for Falmouth is summarized in Table 2 below.

Table 2: Falmouth Demographics

		Falmouth	**U.S.**
Population	Total #	31,531	--
Density	Persons/sq mile	715.0	--
Households	Total #	14,069	--
Age	Median age	51.9	37.3
Race	% White	91.9	74.0
Income	Median HH Income	$61,685	$53,046
	% Pop under Poverty Level	7.5	15.4
Education	% Pop over 25 with bachelor or graduate degree	41.8	28.8

Source: (U.S. Census Bureau, ACS 2009-2013; U.S. Census Bureau, 2010 Census)

The median age in Falmouth, 51.9 years old, is almost 15 years older than the national median age. Falmouth residents are significantly whiter as well, with 91.9% of the population identifying as white, while the national average is only 74%. The median household in Falmouth earns about $8,639 more than in the rest of the country. Educational attainment levels are also elevated, with 13% more of the population possessing a bachelors' or graduate degree than in the general national population.

4.4.5 Technical Components of Sanitation Scheme

The Falmouth Eco-Toilet Demonstration Program has managed to coordinate public funding, participant recruitment, educational information, regulatory pathways, and research monitoring for a pilot municipal ecosan scheme, an impressive accomplishment and the first of its kind in the U.S. The program, however, does not include centralized management of ecosan residuals. Though committee notes of the oversight group, the Falmouth Water Quality Management Committee (WQMC), reveal that some initial intentions for the program included ideas for centralized treatment and reuse, these ideas were not realized as the program developed (Falmouth WQMC, 2012). Despite this lack of centralized residuals management, I classify the Falmouth program as a community-scale and public sanitation scheme due to its consideration as a potential community-wide alternative to sewering, and for the publicly allocated and managed funds and programming it involved. Technical components of the Falmouth sanitation scheme are summarized graphically in Figure 13.

Falmouth Eco-Toilet Program | Functional Groups Flow Diagram

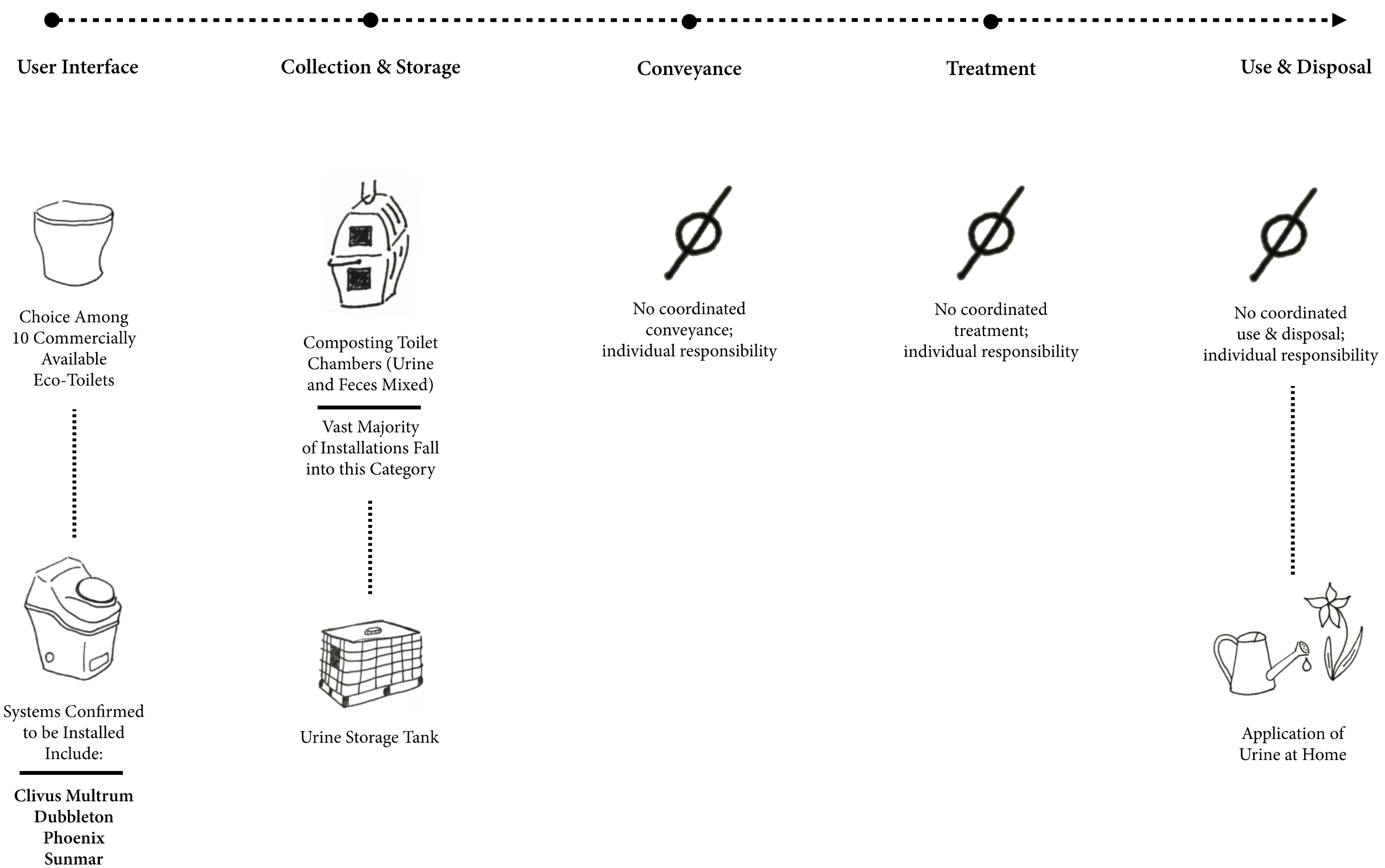

Figure 13: Falmouth Functional Groups Flow Chart

User Interface: The Falmouth project offered a range of commercially manufactured eco-toilet options to prospective participants in the program. The full list of eco-toilets approved for the program is attached as *Appendix D*. Overall, the 10 toilet models approved fall into two categories: (1) Dry toilets, also known as composting toilets, source-separate urine and feces from wastewater streams and store them in holding containers, and (2) Urine diverting (UD) flush toilets, which rely on a fixture to source separate urine from the wastewater stream while also allowing for micro-, foam- or vacuum-flushing of feces.

Costs for each system were estimated to range from at least $5,000 to as much as $25,000 or more, with full costs typically depending on installation conditions. One participant in the program has reported that it cost between $17,000 and $20,000 for his two-occupant household to install two eco-toilets in their home (Driscoll S. F., 2014). Some eco-toilet models are more adaptable than others for retrofitting into existing bathrooms. Six of the eco-toilets are manufactured by companies with U.S.-based operations: Clivus Multrum, EcoTech Carousel, Envirolet, Full Circle, Phoenix, and Sun-Mar. Swedish companies manufacture the remaining four models: Aquatron, Dubbletten, Separett, and Wostman.

Collection & Storage: Collection and storage systems are built into the infrastructure of most commercial eco-toilet systems. Composting toilets with attached composting bins, such as the Clivus Multrum and Phoenix models, typically mix and store urine and feces together in an onsite composting chamber. Composting chamber sizes are selected according to the number of users, and are often designed to treat residuals through naturally occurring thermophilic composting processes over time.

Eco-toilets with UD fixtures offer a conventional wastewater flushing mechanism for feces. In these systems feces is flushed into the septic system along with household greywater, while urine is stored separately onsite at the residence until it can be pumped, transported, and treated before disposal. MassDEP regulations for the UD systems used in the project require that urine be stored in approved septic tanks. According to one report, 500-gallon tanks are being used for urine storage in the project (GHD Inc., 2013). According to other sources, however, a diversity of storage tank sizes is being employed. For example, when one program participant ordered a UD Dubbletten toilet for the demonstration program, the Dubbletten company donated several 350-gallon urine storage tanks to the Falmouth WQMC in support of the program. The storage tanks include an alarm feature that automatically notifies the user when urine levels reach the 300-gallon marker (Patrick, personal communication, 2015). Other participants in the program have reporting installing smaller 50-gallon urine storage tanks at their residences (Driscoll S. F., 2014).

Conveyance / Treatment / Use & Disposal: No centralized management plans for eco-toilet residuals were arranged by the program. In the absence of centrally coordinated plans, the WQMC determined that individual households would be responsible for emptying, transferring and treating or eliminating their eco-toilet residuals. This stance was not always the intention of the program, however. The Falmouth webpage describing the Eco-Toilet Program declares that one of its goals is to “assist in setting up processing and marketing facilities for the urine and biosolids collected from eco-toilets” (Falmouth WQMC, Eco-Toilet Projects, 2012). The Town Meeting Article that approved funding for the program specifically indicated that allocated funds would be used for “the development of a system for compost/urine management” among other goals (Article 17 Town Meeting Vote, 2013). Though early meetings of the Eco-Toilet Subcommittee touched on the need to determine a beneficial use purpose for the residuals and explored options for establishing a local composting site, no concrete developments ever emerged (Falmouth WQMC, Eco-Toilet Subcommittee, 2012). As far as can be ascertained, none of the eco-toilet systems installed for the program have required emptying to date (Heufelder, personal communication, 2015). In the absence of centralized plans, some program participants have expressed interest in recycling limited amounts of urine onsite at their residences in place of commercial fertilizers (Patrick, personal communication, 2015).

4.4.6 Program Operation and Management

O&M aspects of Falmouth’s programming can be described as highly formalized, technology-oriented, framed within existing regulations, fairly bureaucratic, and ultimately similar to the municipal management of conventional sanitation systems. Specific aspects are reviewed below.

Project Initiation: Crisis and Debate: The eco-toilet project in Falmouth originated in the context of a nutrient pollution crisis devastating the area’s ecosystems and stressing the municipality’s budget prospects. When a group of citizens called for alternative approaches to resolve the problem, some Falmouth residents regarded the proposal for eco-toilets as 'too late' within a long public process that had ruled it out at an earlier stage. Others, believing that a sewer solution was inevitable, argued that stalling sewer installation would only raise future costs for the town. Antagonisms developed as the issue became polarized between sewer-based and alternative options. (Cassidy, 2012) (Cassidy, 2014).

Even though the results to date from the demonstration project have unquestionably supported the implementation of community-scale ecosan as a highly efficient nutrient management strategy, many Falmouth residents believe that the topic of eco-toilets is too unpopular or challenging to pursue at a broad level (BCDHE, 2015). In other words, the initial reaction to this topic continues to overshadow current findings, despite impressive results from the research component of the project thus far.

Antagonisms established during earlier political debates seem to have carried into later stages of the project. Some initiators of the eco-toilet campaign felt spurned when the program formalized without including them as decision makers in the bureaucratic town governance structure. Those in municipal leadership positions have also expressed experiencing antagonisms from eco-toilet campaign initiators over the course of the project (Munro, personal communication, 2015). It is possible that the desperation surrounding the introduction of the ecosan concept in Falmouth has imparted on it a polemic characteristic, which it has retained through the demonstration program's implementation.

Community Base: Engaged Citizens & Responsive Government: The community base that promoted the eco-toilet alternative in Falmouth arose from broad political- and environmentally-based social networks that previously existed in the town. A Falmouth resident and previous MA Representative (2001-2010), Matt Patrick, contacted the leaders of a local environmental non-profit organization, *The Green Center, Inc*. to initiate the eco-toilet campaign in early 2011. Together, these actors combined their established social networks with impressive knowledge and resources to mobilize rapid grassroots support for the demonstration project. Their campaign combined concerns for environmental sustainability and economic justice. According to supporters, eco-toilets were not only more ecologically responsible than sewering, but were more economically responsible too. The high costs of sewering improvements, they argued, would stress and eventually displace lower-income families in the town over time (The Green Center, Inc., 2016). The campaign succeeded in mobilizing a significant portion of the town so that in May 2011 a majority of voters at Falmouth Town Meeting approved funding the eco-toilet demonstration program.

Though the campaign was successful in organizing information, resources, and grassroots support for the initiative, it revealed a lack of broad local *professional* capacity to support large-scale installation and maintenance of eco-toilets in the area. Few local engineers, plumbers, architects, or commercial distributors in Falmouth or the surrounding area are familiar with ecosan technology systems. With the intention of building this local capacity, the WQMC oversight group chose to hire a local environmental engineering consulting firm, Science Wares Inc. to manage the eco-toilet program rather than hire experts from outside of the community. On the one hand, this decision reflected a commitment to expanding local expertise, but on the other hand, the local firm lacked previous experience with implementing ecosan systems (Munro, personal communication, 2015).

Once the project was underway, the managing firm strategically decided to encourage as many plumbers as possible to oversee installations of the eco-toilets in the effort to broaden local familiarity with the systems. Participating households were encouraged to select their own plumber regardless of experience, and as a result about seven different plumbers worked individually on the ten eco-toilets installed through the program. For most of the plumbers, this was their first experience with eco-toilet technologies, and though the 'educational experience' this opportunity represented sometimes resulted in 'confusion,' ultimately all installations were successful and plumbers were reportedly 'supportive' and 'fine' with the experience (Karplus, personal communication, 2015). In addition, a number of local stores were encouraged to stock products required for eco-toilet system installation and maintenance.

Formalization: Municipal Oversight & Privately Contracted Administration: The Falmouth Town Meeting vote in May 2011 formalized the eco-toilet grassroots initiative as a municipal program. The Falmouth Board of Selectmen appointed a Water Quality Management Committee (WQMC) to administer all of the alternative nutrient reduction strategies approved in the May vote, which include experimental demonstration projects with shellfish harvesting, inlet widening, permeable reactive barriers, and denitrifying septic systems. An Eco-Toilet Subcommittee of the WQMC formed to oversee the eco-toilet program independently. One of the initiators of the campaign is on the subcommittee (Munro, personal communication, 2015).

All members of the subcommittee were volunteers, and only two individuals have been employed by the project. As previously explained, the Eco-Toilet Subcommittee of the WQMC hired ScienceWares, Inc., specifically Sia Karplus, as technical manager of the program and hired the BCDHE to perform the scientific monitoring of septic tank effluent (GHD Inc., 2013). Participants in the project have shared their views that the formalization of this project as a municipal program with endorsement from the county health department lent a legitimacy factor that helped the program to navigate subsequent regulatory barriers (Karplus, personal communication, 2015).

Funding: Municipal Funds: When the Eco-Toilet Demonstration Program was approved at Falmouth's Town Meeting in May 2011, $500,000 in municipal funds were allocated to fund the demonstration project. Another $150,000 was allocated for the installation of composting toilets at public sites in the town (Article 17 Town Meeting Vote, 2013). As of September 16, 2013, the WQMC had committed $190,000 of the funds to specific uses, leaving $310,000 to be occupied in subsequent phases, plus the funds for the public installations (GHD Inc., 2013). This funding approach has been advantageous in that a fairly large and secure amount of money was swiftly secured for the project. The public nature of the funds, however, also limits their potential uses.

For example, disagreement arose during the planning process of the program in response to a proposal to fund a public demonstration site with a fully functional eco-toilet at the headquarters of a local non-profit. The proposed location for the demonstration toilet was at *The Green Center, Inc.,* the non-profit group that helped garner initial support for the eco-toilet demonstration project and that independently opened the *Cape Cod Eco-Toilet Center* to showcase various eco-toilet technologies for the public.

To some, this proposition seemed logical since most prospective participants in the program visited the non-profit's *Eco-Toilet Center* to view various toilet models and learn about the science of ecosan systems before deciding whether or not to enroll in the program. Additionally, the Eco-Toilet Subcommittee was struggling to find a receptive location for the public toilets included in their budget. Ultimately, the proposal to install a public demonstration toilet at *The Green Center* was rejected because it was determined that public funds could not be used for the benefit of a private interest group, such as a non-profit. To date no further plans have been made to establish a public demonstration site for the program (Munro, personal communication, 2015).

Public Education & Participant Relations: Showcases & Vetting: Previous to approval of the program, the grassroots coalition of eco-toilet advocates organized an Eco-Toilet Summit on the Cape in the spring of 2011. The summit aimed to educate Falmouth citizens about eco-toilet technologies in advance of the May 2011 Town Meeting approval vote. After Town Meeting approved the project, another educational summit was held in July 2011. These early efforts in public education called on academic and professional perspectives to bolster the argument for eco-toilets. Flyers for the events can be viewed in *Appendix C*.

The need to establish a public site in Falmouth to concentrate information for prospective participants in the program became clear to advocates. *The Green Center Inc*. non-profit group opened the *Cape Cod Eco-Toilet Center* in the fall of 2012 to make available for public viewing a full array of the eco-toilet models eligible for consideration in the program. The eco-toilet showroom was established at the non-profit's headquarters, less than fifteen minutes drive from downtown Falmouth. The showroom hosted public workshops and weekly visiting hours. None of the toilets in the showroom, however, were fully installed and functioning toilets.

To encourage Falmouth residents to join the program, the Eco-Toilet Subcommittee established a series of incentives to aid participating homeowners in their adoption of an eco-toilet system. The two most widely advertised incentives were a $5,000 subsidy grant to participating households to help cover installation costs, and a free septic system pump-out valued at $300. Additional incentives were also available, but it seems these benefits were not as successively advertised as the previous two. Additional benefits included access to a forgivable $5,000 loan to assist in eco-toilet installation costs, tax credits with a value as large as $6,000, and a sewer betterment exemption program that would exempt households from a future $18,000 betterment and hookup fee (Heufelder, personal communication, 2015). Only two of the ten households confirmed to have participated in the eco-toilet program enrolled in the sewer betterment exemption program (Driscoll S. F., 2014).

Low enrollment in the demonstration program has caused many to ask if the incentive package provided was insufficient. Project manager, Sia Karplus, concludes that costs for individual eco-toilet installations have been higher than anticipated, though cost concerns have not been a major reason for declining to participate in the program. The main reasons most families deferred participation had to do with aesthetic concerns or worries about the resale values of their homes, and not costs alone (Karplus, personal communication, 2015).

Numerous regulatory requirements for the eco-toilet program (outlined in the following section) constituted a significant vetting process for prospective participants in the program. From the more than 152 households that originally expressed interest in installing an eco-toilet, only about 10 have been confirmed to have qualified and registered with the program. Factors that influenced households' decisions included affordability, personal preferences, and logistical factors, but strict program requirements have also excluded some interested households. For example, one residence was excluded after having managed to comply with regulatory requirements, but failed to begin installation construction before a certain date (Driscoll S. F., 2014). More interested parties claimed to have been unaware of specific permit or installation deadlines until after they passed (Barnhart, personal communication, 2015).

A significant hurdle presented to interested households was a site visit logistics check, a process that cut eligible households in half (GHD Inc., 2013). Karplus, who performed 44 site visits, explains that logistical constraints wherein eco-toilets would simply not fit in existing homes was a significant reason for this drop-off, along with conversations with prospective participants about the unexpected 'realities' and responsibilities of owning an eco-toilet (Karplus, personal communication, 2015).

Many Falmouth residents have been surprised and highly curious about the local ‘disinterest’ in the eco-toilet program following its enthusiastic approval (Driscoll S. F., 2014; O'Brien, 2014). Some initial supporters have wondered if inexperience and a focus on technological barriers on the part of the managing engineering firm or the WQMC limited the project by disallowing toilets in homes where a more experienced ecosan expert may have found solutions (Barnhart, personal communication, 2015). While such allegations are difficult to verify, they underscore the lack of local ecosan expertise in Falmouth. Ultimately, it is clear that many factors coincided to create a significant participant vetting process, and that the overall appeal of participating in the eco-toilet project declined over time.

Regulations: State Plumbing Variance & Individual HH Permits: For the program, individual eco-toilet installations had to comply with both state and local regulations. Firstly, specific eco-toilet models had to be approved for installation in the state of Massachusetts. Five of the eco-toilets already had ‘Product Acceptance’ status in MA under the ‘alternative systems’ designation of Title 5 regulations for onsite wastewater systems. To include UD flush toilets in the program, however, the project manager had to seek a ‘Test Site Status’ variance from MA’s Board of State Examiners of Plumbers and Gas Fitters (BSEPGF) in March 2013, since UD fixtures are not permitted by existing state regulations. The BSEPGF variance allowed for up to forty pilot UD installations (Munro, personal communication, 2015). The WQMC ruled out the option of stand-alone urinals for urine collection since navigating state regulations for such systems would be too cumbersome for the project (Falmouth WQMC, 2012).

In addition to using a toilet approved by MA BSEPGF, each household in the program was required to obtain a plumbing permit, apply for Falmouth Board of Health approval of a written maintenance plan, coordinate with the BCDHE for the viability of septic testing at their site, arrange for eco-toilet installation by a licensed plumber, and gather signatures for an Incentive Contract to gain access to the eco-toilet incentive package provided by the town (Munro, personal communication, 2015). Though the project manager centrally coordinated much of the permitting process, many observers link the burden of requirements placed on program participants to low enrollment in the program.

Research: Data for Regional Planning Purposes: Though the Falmouth Eco-Toilet Program has several goals to enhance understanding of eco-toilets, one particular research project was formalized in partnership with the BCDHE. Representatives of the BCDHE were charged with measuring the ability of UD eco-toilets to reduce nutrient loads residential septic tanks. To do this, residences had to consent to regular testing of their septic tank effluent following eco-toilet installation. The results of the study are intended to help the WQMC decide if eco-toilets present a viable alternative to sewering and should be included in Falmouth's CWMP.

To commence testing, a household first had to meet all of the requirements for the program and submit their Incentive Contract to the town. Subsequently, a representative from BCDHE sampled effluent from the residence's septic tank to establish a baseline measurement of nitrogen outflow for the site. Upon installation of the eco-toilet any non-eco-toilets remaining in the house would be disabled, removed, or blocked off to guarantee that the residence would only occupy the eco-toilet system for the entirety of the monitoring period. The program required that a licensed plumber install the eco-toilet in the participating home, and upon installation the town paid for a full pump and clean of the household septic tank to 'reset' it for subsequent effluent testing (Heufelder, personal communication, 2015).

Following eco-toilet installation, samples of septic tank effluent were taken at each residence by representatives of the BCDHE over a ten-month period. Preliminary findings of the monitoring program overseen by BCDHE have shown that the urine-diverting eco-toilets have been effective in diverting up to 90% of human excreta nutrients from household septic systems, though the amount sequestered depends on which eco-toilet model used. The preliminary findings are outlined in a report prepared for the WQMC (BCDHE, 2015).

4.4.7 Role of Planners

The regional planning commission for Barnstable County, the CCC, has played a significant role in overseeing the design of Falmouth's CWMP. Some Falmouth residents, though, have characterized the CCC's presence as obstructive and even misleading when it came to the topic of experimental technologies and eco-toilets (Barnhart, personal communication, 2015). When CCC officials were critical of initial Falmouth proposals to pilot eco-toilets and other alternatives, "a split developed between planners, who, critics argue, are biased in favor of traditional sewer systems and citizen activists or entrepreneurs promoting sometimes unproven alternative technologies" (Cassidy, 2012). Some Falmouth residents argued that the CCC planners were biased in support of sewering. CCC officials responded that regional planners typically start with a bias against sewering, despite popular notions (Ibid.)

Polarized debates and antagonisms that developed between professional planners and grassroots interests on the Cape reflected the broader split between proponents of alternative technologies and those who have seen conventional wastewater treatment as the only legitimate way forward in Falmouth. After receiving backlash and an influx of information from proponents of alternative technologies, the CCC shifted its position to be more supportive of the experimental strategy proposed in Falmouth. Antagonisms cooled when the commission approved the town's CWMP along with its allocations for alternative technologies.

In its 2015 Section 208 Update Plan, the CCC professed a supportive stance for lower-cost alternatives to sewering, recognizing the financial burdens that Cape-area municipalities face in addressing wastewater management decisions (Cape Cod Commission, 2015). Additionally, the executive director of the CCC has professed that at least half of the costs for improving Cape Cod's coastal waters should be met by state and federal agencies, and not by the municipalities alone (Cassidy, 2012).

4.5 Comparative Analysis

Both the Rich Earth Institute UNRP and the Falmouth Eco-Toilet Demonstration Program have marked impressive milestones in organizing, regulating, and financing their respective ecosan projects as the first projects of their kind in the U.S. While the projects share some contextual characteristics linked to their initiation, they also have evolved to become unique programs. A number of project similarities and differences are reviewed here, and lessons are summarized as opportunities, challenges, and strategies in the following chapter.

4.5.1 Similarities

Perhaps the greatest parallel shared by the projects is their initiation by strong citizen groups within the community. Truly bottom-up mobilizations in each community managed to garner wide attention and receptivity to previously unheard of proposals for community-scale ecosan implementations. Certain similarities in the populations of Brattleboro and Falmouth may indicate social environments where this degree of community support for ecosan can arise. Both towns are predominantly white, with almost the same proportion of white-identified persons in the population, 92%. Both populations are highly formally educated relative to national averages, and median ages are older than in the general national population.

For both the REI and Falmouth programs, scientific research goals oriented project development over time. Interestingly, this research orientation also seems to have enhanced local appeal of participating in the projects. As previously mentioned, many urine donors to REI's UNRP reported feeling motivated by the opportunity to contribute to a scientific study. Comparably, a participant in the Falmouth program reported an interest in ecosan science as a motivation for joining the project, explaining, "My wife and I are both science types, and we're interested in the whole process" (Driscoll S. F., 2014).

Both programs have captured the attention of intellectually curious citizens who seem willing to undergo transitional discomforts in the interest of broadening their knowledge bases. Participant interest in the scientific and research processes of ecosan systems may be connected to generally elevated education levels in the communities. Though a number of demographic qualities are comparable between the towns, an equal number of differences in the populations are notable. A side-by-side demographic comparison is provided in Table 3 below.

4.5.2 Differences

Beyond common factors linked to initiation, the programs exhibit more differences than similarities. Differences range from varied environmental conditions, to distinct motivations, to dissimilar approaches to program O&M. Demographic factors in the Brattleboro and Falmouth communities are not entirely analogous either. Falmouth is almost twice as densely populated as Brattleboro. The average household in Falmouth makes at least $16,000 more than in Brattleboro, and its population is older with many more senior citizens residing in the town. Higher household incomes may be linked to Falmouth's slightly larger portion of the population with college-level studies. Uniquely, Falmouth has many more part-time residences than either Brattleboro or the U.S. in general. One in three Falmouth homes is designated for part-time and recreational uses. A comprehensive summary of additional program differences is summarized in Table 4.

Beyond demographics, unique conditions of geography and land use have given rise to divergent qualities in each initiative. Brattleboro's prevalence of agricultural land uses has encouraged REI to focus on the agricultural applications of ecosan systems, whereas Falmouth's delicate hydrologic circumstances has required its initiative to focus on nutrient pollution remediation to the exclusion of additional ecosan benefits.

Table 3: Comparative Town Demographics

		Brattleboro	Falmouth	U.S.
Population	Total #	12,046	31,531	--
Density	Persons/sq. mile	376.4	715.0	--
Households	Total HH #	5,562	14,069	--
	% HH with individuals 65 and over	25.9	40.4	25.5
	% HH for seasonal, recreational, or occasional use	1.7	32.3	3.5
Age	Median age	44.7	51.9	37.3
	% Pop over 40	54.1	71.8	46.3
Race	% White	92.1	91.9	74.0
Income	Median HH Income	$45,119	$61,685	$53,046
	% Pop under Poverty Level	16.2	7.5	15.4
Education	% Pop over 25 with bachelor or graduate degree	34.4	41.8	28.8
Similar		**Different**		**Outlier**

Source: (U.S. Census Bureau, 2009-2013; U.S. Census Bureau, 2010)

Table 4: Key Differences Between Programs

	Brattleboro	Falmouth
Introduction	Complementary to existing sanitation practices; optional activity for community volunteers	Contentious; Political debate over use of public funds; polarization of topic between sewers and alternatives
Goals	Divert urine from waste stream; produce fertilizer; perform experimental field trials; develop progressive U.S. regulations for UD and reuse; public education and advocacy	Assess eco-toilets as nutrient pollution reduction strategy; gauge public receptivity; understand cost and regulatory barriers; a goal to process residuals was not realized
Scope	>150 individuals and HHs	~10 HHs
Formalization	Non-profit organization	Municipal program
Leadership	Initiator-led and managed	Municipal committee oversight and private consultant administration
Local Expertise	High	Low to medium
Public Education	UDDT demonstration toilet; portable public UD toilets; entertaining public presentations and conferences	Showroom to display eco-toilet models independently created by non-profit; no public toilet installations
Funding	Donations and grants	Municipal Funds
Partners	Septic business, farms, WWTF, universities and research institutions	County board of public health
Regulation	Environmental permits for non-profit activities	State plumbing variance and individual HH permits
User Interface	Varied low-cost options highly adaptable; designs evolved to incorporate user feedback; somewhat informal use	Varied high-cost commercial models; low adaptability to some retrofit conditions; high formal replicability
Residuals Management	Centralized; Reuse as a local free fertilizer	Individual responsibility
Research	Research topics have changed over time; results shared with project participants	One specific research project coordinated
Incentives	Opportunity to participate in research study	Access to financial package of grants, loans and exemptions
Planner's Role	Distant and supportive	Involved; initially discouraging; ultimately approving

When Falmouth eco-toilet proponents initiated their campaign, the town was already stressed by environmental degradation and financial strains to pay for a wastewater solution. The dire environmental degradation in Falmouth placed stress on public actions to remediate the problem, and, accordingly, on the eco-toilet initiative. REI, on the other hand, was able to propose their UD 'peecycling' project in a relatively proactive and agreeable manner in Brattleboro. The timing of project introduction has been shown to be influential on subsequent program success (Johansson, Kvarnstrom, & Stintzing, August 2009).

The distinct formalization paths taken by the initiatives contributed to several differences in project O&M. Since the Falmouth program was formalized as a municipal program, it has experienced relative inflexibility in terms of use of public funds, community partnerships, permissible eco-toilet prototypes, leadership options, and the development of centralized collection and treatment of eco-toilet residuals.

These inflexibilities have placed certain limitations on the Falmouth Eco-Toilet program, but there are ways in which municipal formalization has proved advantageous for Falmouth. For example, the regulatory variance granted to allow UD fixtures to be installed for the pilot program were achieved in connection with legitimacy factors granted by public status of the program. Funds allocated through public vote were secure and substantial, granting a sense of stability to the Falmouth project that REI has not yet achieved in the short-term. It is important to note here that the municipal management of Falmouth's program may also represent a more familiar and replicable approach for sanitary reform in communities across the U.S. than the non-profit method of REI.

To establish a positive relationship with local professional planners REI sought contact and guidance from their local planning commission, who has responded with enthusiastic support for REI's project. In Falmouth, where professional planning oversight is required for the town's CWMP process, attitudes have been quite different. Many Falmouth community members have reported that the Cape Cod Commission (CCC) actively antagonized local campaigns for eco-toilets during early stages of the proposal, impacting political processes significantly. The experiences of both projects show that professional planners can adopt positive or negative stances on community ecosan initiatives, and that their professional influence can impact local attitudes.

4.6 Closing

The experiences of the two pilot projects demonstrate that community ecosan schemes have been received positively in communities with majority white populations, high levels of formal education, and an aging populace. Experiences indicate that large-scale UD ecosan proposals arise from community-based advocacy campaigns with environmental and economic motivations. Projects can pursue various pathways for formalization, funding, regulation, and networking. Chapter 5 synthesizes case study findings further to articulate some emergent trends for community ecosan implementation in the U.S. context.

CHAPTER 5

DISCUSSION

5.1 Opening

This chapter condenses the rich and mixed experiences of the cases described in Chapter 4 into action-oriented conclusions about emergent trends in U.S. ecosan practice and sanitary reform. Opportunities and challenges for community ecosan are outlined, as well as strategies that projects have adopted to overcome barriers. A discussion of the roles that community members and professional planners can and are playing to reform U.S. sanitation practices follows with reference to a number of applicable tools and techniques.

5.2 Integration: Opportunities, Challenges, and Strategies for U.S. Ecosan

Lessons from recent pilot experiences in large-scale UD ecosan coordination provide the opportunity to illuminate broad trends about how these systems operate in the U.S. Though the experiences of the two projects should not be generalized far beyond their individual contexts, the dearth of existing ecosan precedents in the U.S. creates a need to extrapolate preliminary lessons from available examples. The conclusions presented here are by no means definitive, but intended to advance nascent discussions in the U.S. institutional context.

5.2.1 Opportunities

Based on common characteristics of the two pilot programs, certain community attributes can be identified to indicate potentially welcoming environments for the introduction of community ecosan experiments in the U.S.

Opportunities appear to exist in places with sustainability-inclined populations, mid-to-low density settlements, and local agricultural land uses. The broad nature of these characteristics suggests that many locations in the U.S. may be open to piloting large-scale ecosan projects.

'Green Citizens' & 'Green Centers': Identifying Green Communities: In Brattleboro, sustainability-oriented 'green citizens' initiated conversations about peecycling at the local food cooperative and with their neighbors. In Falmouth, individuals associated with the 'Green Center' non-profit garnered rapid support for their eco-toilet campaign through educational conferences and showcases. Evidently, both communities are home to publicly engaged citizens that demonstrate powerful concerns for environmental sustainability and local self-determination.

Recently, such qualities have been associated with a 'green citizenship' socio-cultural phenomenon in the U.S. According to political scientist Andy Scerri, 'green citizens' embrace post-materialist values related to ecological sustainability, global human rights and concerns about self-actualization and quality of life. Typically, these citizens are more concerned about local governance and globalization trends than nationalized state politics (Scerri, 2012). I find these qualities highly characteristic of participants in the Brattleboro and Falmouth ecosan programs, and somewhat more broadly in each community. If 'green citizen' qualities characterize communities where ecosan has been adopted to date, then other 'green communities' may represent potentially hospitable sites for ecosan.

The task becomes identifying these green communities. Places with collective activities such as recycling and composting programs present excellent candidates. The applicability of this logic to the case of REI is demonstrated in the group's original UNRP description, which states, "just twenty-five years ago the recycling of household trash was unheard of, and now it is the norm" (Rich Earth Organization, 2012, p. 1). By arguing that peecycling can become as commonplace as recycling practices, REI reveals its position as an exceptionally progressive community. Though recycling has achieved 'norm' status in Brattleboro, a majority of U.S. communities are far from having achieved this stance. Green communities are ones that have already embraced activities like residential recycling, composting, and energy- and water-conservation practices.

Beyond sustainability-centered values, other characteristics of the case studies provide indicators. According to the case studies, communities with predominantly white, college-educated, and aging populations could be more receptive to community ecosan schemes. Age may be a factor since older individuals tend to live more stable, less volatile, lives than younger generations, and stability could ease the transition to adopt UD ecosan practices. Also, older individuals may be more likely to be homeowners than renters, affecting their ability to alter a residential toilet or collection system. High education levels may be relevant to ecosan adoption due to their association with enhanced intellectual curiosity, openness to new experiences, and higher income levels.

The affluence, stability, and social security that can be granted by higher income levels may also explain why predominantly white populations are more receptive to ecosan system use. Since white-identified individuals typically experience more security in terms of race and class positionality, they may be less daunted by the potential social stigmatization associated with ecosan adoption. In other words, highly educated white-identified individuals have enough cultural capital that they are able to take more social risks than other social groups.

The relevance of cultural capital to ecosan adoption has been recognized previously in the ecosan literature. As early as 2004, Winblad and Simpson-Hébert. advised ecosan advocates to target respected and powerful ‘model families’ for program participation due to their ability to “convert” others to ecosan toilet acceptance (2004, p. 107). More recently, Allen & Conant argued that the introduction of community ecosan practices to the U.S. could trigger an international tipping point for ecosan acceptance, explaining, “As a major world power and an exporter of both culture and technology, the United States of America has a unique ability to affect the perception and acceptance of sanitation technologies globally” (2010, p. 29).

Though green communities represent a fairly narrow section of the U.S. population, the influence of this sector may be considerable. Scerri notes that ‘green citizens’ have been referred to as the “new middle-class cultural elites” for their ability to shape societal attitudes through popular campaigns and knowledge generation (2012, p. 77). In accordance with this observation, green communities can have a history of popular sustainability campaigns, which in turn establishes regulatory environments and institutional arrangements that are relatively open to innovative technologies. Examples include communities with active ‘Transition

Town' groups, MA towns designated as 'Green Communities', communities with sustainability-oriented businesses such as solar power or market cooperatives, and towns with campaigns for locally sourced products, school or public gardens, and farm-to-table programs.

Locations with Agricultural Uses and Sanitary Needs: Places with certain physical and land-use characteristics may also be well-suited to ecosan scheme implementation. The Falmouth and Brattleboro cases present different physical conditions that gave rise to their ecosan activities, and both are instructive. In Falmouth, delicate hydrologic conditions and advanced ecological degradation due to inadequate sanitary systems already in place catalyzed swift approval of the pilot ecosan program. In Brattleboro, abundant agricultural uses in the town and fairly low-density settlements presented a persuasive opportunity for the implementation of an ecosan scheme that would process and reuse urine fertilizer nutrients locally.

Opportunities also exist in small, rural and historic towns where residential density has increased gradually over time, or where existing septic or sewer arrangements have degenerated to the point of failure. The small municipal budgets of these areas likely prohibit public investment in expensive centralized systems, and low density can make this option impractical as well. Decentralized ecosan systems that can cost much less than new septic installations and do not require the leach field real estate can present a positive alternative.

In sum, locations with agricultural land uses and with failing or inadequate sanitary infrastructures could present opportunities for ecosan implementation. Mid-to low-density settlements offer space for residuals storage, transportation and processing. These densities also typically preclude centralized sewer installations as a community sanitation approach. In these cases, ecosan options compete with septic solutions, which can be more expensive and occupy more land than the ecosan systems. Some planners have seen small rural and peri-urban communities currently in economic and physical decline as candidates for community ecosan applications for the systems' low relative costs and network modularity.

5.2.2 Challenges

Despite their many accomplishments, the pilot UD ecosan programs have not been immune to barriers challenging the implementation of new and unfamiliar sanitation systems. I have grouped some of the more common and formidable challenges into the categories of institutional path dependence, bureaucracy, technocracy, and user receptivity.

Institutional Path Dependence: The greatest challenge facing large-scale ecosan implementation in the U.S. is institutional inflexibilities regarding sanitation planning. Existing pathways for developing, regulating and funding sanitation solutions almost exclusively recognize and prioritize water-based and buried systems. For example, in many states regulatory language for the oversight and installation of eco-toilets is still vague and tends toward prohibition. Allen and Conant summarize this state of alternative sanitation regulations in the U.S. as "prohibitive at worst, and unclear at best" (2010, p. 27). No states currently regulate source-separated anthropogenic urine as a residual distinct from sewage or greywater. Some funding structures are in place to subsidize the repair or expansion of sewer and septic systems, but rarely do such financial incentives incorporate alternative sanitation technologies.

The lack of professional familiarity with these systems further limits their adoption. As was the case in Falmouth, municipalities often contract private engineering consultants to provide assessments and recommendations for local sanitation planning. In a 2007 report the professional consultants hired by Falmouth in years previous to the Eco-Toilet Demonstration Program ruled out alternative sanitation approaches due to "uncertainty of their performance and acceptability" (GHD Inc., 2013, p. 3.8). The 2007 report concluded that town-wide sewering was the best option and recommended that Falmouth pursue plans to sewer as soon as possible. In a 2013 follow-up report, however, the consultants revised this conclusion, explaining that "additional information on the efficacy and suitability of eco-toilets has become available, warranting their inclusion" as an alternative for consideration (Ibid). In the interim Falmouth citizens had organized an educational campaign to introduce the consultants and the local community to internationally based data on the advantages of ecosan solutions.

Clearly, information about ecosan systems is lacking in the U.S., but more structural barriers also seem to bias institutions toward conventional solutions. Some ecosan advocates point out that consultants such as those hired by Falmouth are motivated by implicit self-interest when they recommend conventional solutions since towns can turn around and hire the same consultant groups to design and build the recommended, and expensive, wastewater infrastructures. It would be contrary to this self-interest for an engineering firm to recommend that a town implement alternative and lower-cost technologies with which the same firm is unfamiliar.

To address these questions of information access and inherent professional bias, education about sanitation alternatives should begin earlier in sanitation professionals' training. If ecosan and other alternative approaches are to become more popular in the U.S. then massive educational and awareness campaigns will have to prepare the current and future generations of sanitation professionals (regulators, engineers, and public policy makers) to consider a more diverse array of sanitary options. The proliferation of ecosan practices in the U.S. will require new regulatory language and funding sources to support responsible community-based innovation.

Bureaucracy: Linked to issues of institutional path dependency, bureaucracy can arise as a challenge to effective ecosan implementation in the U.S. The Falmouth experience in particular demonstrates that efforts to formalize community ecosan through existing institutional pathways burden projects with regulatory obligations to the extent that they become impractical for average citizens to participate in. Also, conventional models for sanitation planning and management are highly professionalized and generally removed from public engagement. If community ecosan projects conform to these management tendencies, they may risk losing touch with the community bases that initiate them and grant them their local legitimacy.

For example, the Falmouth program followed fairly conventional pathways for regulating and managing their Eco-Toilet Program. While these pathways granted the program benefits of legitimacy before state and local regulatory institutions, it also created considerable barriers for prospective participants in the program. Bureaucratic requirements such as strict deadlines and multiple permitting for individual systems eventually excluded some homes from the program. According to some, municipal oversight and administration of the program by a consultant unfamiliar to initial supporters of the campaign disconnected early community-based enthusiasm for the program from later stages of program implementation.

In contrast, REI evaded conventional formalization pathways by pursuing a non-profit management model. However, this model has presented its own advantages and drawbacks. For example, the non-profit model, with its highly independent leadership and at times informal practices, may not be replicable in communities and states where regulatory environments are less open to experimentation. The engaging and personal management style of the non-profit is extremely energy intensive and demanding in ways that are potentially unsustainable in the long run. More bureaucratic processes can lower management burdens on leaders of ecosan projects, but also introduce their own limitations. Clearly, a legacy of bureaucracy impacts the introduction of new sanitation approaches, and ideal management schemes for community ecosan are not yet clear.

Technocracy: Yet another challenge that arises in tandem with path dependence in sanitation planning is a tendency to focus disproportionately on technological aspects of ecosan systems in implementation. A recent report has demonstrated the prevalence of technocracy in international ecosan campaigns

(Fox, 2015), but technocracy can pervade domestic projects just as easily. When a programmatic focus on technological components limits attention to socio-cultural aspects involved in sanitary practice transitions, ecosan projects can encounter lower user receptivity and more technical complications from system misuse.

Tendency toward technocracy in sanitation planning is tied to historical trends in conventional wastewater system management in the U.S. Sanitation reforms in the 1970s established a technology-centered approach to wastewater treatment standards when they required the application of specific technologies at treatment facilities (Melosi, 2008). Conversely, a performance-based approach allows a range of different technologies to meet specified treatment levels. Ecosan proponents typically advocate for performance-based standards for water and residuals treatment, but a legacy of technology-centered oversight continues to press technocracy on contemporary sanitation planning. Recent research has also found that professional training for engineers in the U.S. perpetuates technology prioritization in program design and implementation (Cech, 2014).

Some observers of the Falmouth project have suggested that a managerial focus on the technical components of eco-toilets limited the program's scope. When asked about reasons for low program enrollment, the Falmouth program administrator explained that social factors were often marginal to decision-making processes. The manager, an environmental engineer, explained, "It's great to think about the political and social factors in installing these toilets, but it really does come down to [questions like] *What does it take to do a retrofit in my house? What is* *it going to mean in terms of my bathroom configuration?*" (Karplus, personal communication, 2015).

Language used by the Eco-Toilet Program manager suggests an inclination to discount social factors in understanding how households made decisions about adopting an eco-toilet. While logistical factors certainly account for a portion of households declining to participate in the program, it seems possible that critics could be right in identifying technocracy in Falmouth's program implementation in general. Current trends indicate that this tendency would not be unique to Falmouth and will likely affect future ecosan projects in the U.S.

User Receptivity: Numerous factors have contributed to mixed user receptivity of ecosan practices in the pilot programs. While the general populations of both towns approved of the practice in their community, ecosan has not been universally adopted or appealing. In some cases, differing attitudes have existed even in a single household. Many factors discussed in the ecosan literature were found to affect receptivity in the New England projects studied, including concerns about aesthetics and odor (the later occurring specifically with urine collection and storage), inconveniences and responsibilities introduced by peecycling or ecosan system ownership and installation, and the dubious acceptability of ecosan practices by family and friends.

In Falmouth, additional concerns arose due to the serious financial investment involved in installing a full eco-toilet system at their residence. Some citizens reconsidered their interest in the program after receiving cost estimates for eco-toilet installation, which in addition to eco-toilet purchase could include costs for home remodeling, piping and burial of storage tanks on the property. Others worried that installation of an eco-toilet could lower the resale value of their homes.

In contrast, costs did not come up as a limiting factor in the REI project, likely due to the lack of infrastructure required for participation in the UNRP. Prospective participants did have serious concerns about controlling the odor of stored urine in their homes, keeping urine storage containers out of sight in their bathrooms, and potentially spilling urine during transportation to REI drop-off depots. Many participants expressed interests in putting UDDTs in their homes, but were unable to pursue these plans due to rental status or lack of space.

The general populations of both towns did express unease when they learned about the CECs concentrated in human excreta residuals. These trepidations were usually tempered by the simultaneous realization that in water-based sanitation schemes CECs and PPCPs undergo no remediation processing at WWTFs and are released into the general environment. Though initially citizens expressed concern about how to dispose of ecosan residuals with high concentrations of contaminants, most citizens later shifted to see ecosan system use as an effective way to isolate these CECs from household waste streams. Participants in the ecosan pilot programs were collectively interested in experiments that could be performed with ecosan residuals to better understand how to break down CECs.

Challenges related to user receptivity of ecosan in the U.S. context are clear. Though some ecosan advocates promote the approach as universally applicable, experiences in the U.S. to date show that only a section of the population may be inclined to use these technologies. Questions remain about what socio-cultural environments are compatible with ecosan adoption, and how ecosan systems can be introduced alongside conventional practices in places where citizens do not embrace the technologies universally.

5.2.3 Strategies for Success

Despite significant barriers to community-scale ecosan program development in the U.S., pilot initiatives have adopted various strategies to deal with challenges as they arose. Tactics used to navigate and even overcome barriers under some circumstances are outlined in this section. I have previously argued in this thesis that project O&M decisions have the greatest impact on ecosan project effectiveness and appeal. The strategies highlighted here, based on experiences from the pilot programs, confirm that decisions adopted over the course of project implementation directly impact success.

User Receptivity: The following practices adopted by the pilot ecosan projects significantly expanded the appeal of ecosan in their communities. Replication of these practices could broaden participation rates and general receptivity of future initiatives.

(1) Pursue and advertise research activities: Both pilot programs designed research goals, and awareness of these scientific pursuits attracted participants to the programs. Integration of research components into future projects and the involvement of participants in research processes are likely to enhance appeal for individual participants in the programs (Dellström Rosenquist, 2005). U.S.-based research results will also increase awareness and understanding of these systems in the nation more generally.

(2) Minimize individual inconvenience: Practices designed to reduce burdens on individual participants in overall ecosan scheme operations were highly effective in making ecosan adoption more accessible among local populations. An important part of meeting this objective is to plan for residuals end-use early on in planning processes, and to centralize processing if possible. The effects of offering incentive packages to participants, particularly financial incentives, are not clear. Winblad et al. warned in 2004 against dependence on significant subsidies in pilot ecosan programs since they can create unrealistic impressions of system costs and ultimately contribute to program failure. Further research is needed to see if financial incentives are a sound method for facilitating ecosan participation in the U.S.

(3) Respond to community concerns: Decisions to listen and respond to feedback from project participants were associated with system effectiveness and participant satisfaction. For example, REI's co-design of user interfaces with UNRP participants integrated the participants and met needs directly and collaboratively. Regular communication and solicitation of commentary from participants sustained a sense of community ownership of the REI program and maintained participant interest over time.

Path Dependence: In response to bias against alternative sanitation approaches in relevant U.S. institutions, the pilot projects have achieved their goals by focusing on local reforms and alternative regulatory and financial approaches. Complementing these local actions with broader networking has advanced the ecosan agenda across the country despite persistent institutional resistance to change.

(1) Innovate approaches locally: Both pilot projects designed unique programs in accordance with local conditions and opportunities. In the near future, it is unlikely that federal and state regulations or funding structures will change to support community ecosan implementation directly. Ecosan projects will have to tap local and alternative financial resources and campaign for local regulatory reforms. Local and state plumbing, building, and public health codes can be reformed more easily in comparison to national standards for environmental, agricultural and housing practices. Development of local experimental and performance-based codes can provide precedents for broader future reforms.

(2) Network for broader legislative and regulatory reforms: Program integration into broader campaigns for ecosan advocacy has increased project exposure and scope in both cases. Falmouth's coordination of public education programming with regional experts and REI's collaborations with groups across the country to reform international plumbing codes amplified influence of the projects significantly. Such networking will be critical if more regional, national and international reforms of conventional practices are to be realized and trends of conventional sanitation path dependence are to be reversed.

Bureaucracy & Technocracy: Tendencies toward bureaucracy and technocracy in ecosan program management can result from the influence of dominant trends in sanitation planning. Awareness of these tendencies and strategies to keep ecosan programs as flexible and person-oriented as possible should improve programming overall in experimental pilot projects.

(1) Incorporate adaptability into program design: A degree of flexibility in project design can allow for wider prospects and greater program resiliency over time. REI's organizational mission and research interests have been open to incorporating new opportunities, partnerships and discoveries. Though too much flexibility can water down programming and invite mission creep, some adaptability can allow community ecosan programs to capitalize on rare opportunities that come their way. Flexibility can prevent tendencies toward bureaucratic management if program goals are focused on program success rather than compliance with rigid expectations. While program flexibility may be more viable in some regulatory and social environments than in others, where possible it can be an advantageous approach.

(2) Orient projects toward people: Project attitudes that have embraced the highly personal nature of sanitation practices and invested in participant relations have encouraged program accessibility and success. To avoid technocratic tendencies in program management, an appreciation of socio-cultural aspects of ecosan adoption should be cultivated. Willingness to discuss the 'ick factor' associated with human excreta management can invite project participants to openly discuss their discomforts and doubts with project coordinators. This personal contact can prevent ecosan system misuse, participant anxiety and project abandonment.

5.3 Sanitation Reform in Action: A Role for Planners?

Analysis of opportunities and challenges for U.S. ecosan has left out a discussion of planners until this point since the pilot programs have shown planners' roles to be ambiguous. Professional planners can act as either supportive or dismissive, integral or marginal forces in mobilizing community-based ecosan proposals. This section takes a quick look at strategies some professional planners are using to actively promote sanitary reforms in their communities. Additional planning tools and frameworks applicable to sustainable sanitation reform are reviewed.

5.3.1 Applicable Planning Tools, Techniques & Frameworks

Some planners increasingly see community-scale ecosan as consistent with planning goals for historic preservation, economic revitalization, growth management, density and infill strategies, and even regional food system resilience. For professional planners interested in advancing sanitary reforms in the U.S. a number of tools could be used to encourage ecosan adoption in communities that express interest in piloting alternative sanitation approaches.

Honey and Eggs… and Compost Ordinances?: Local ordinances can be designed to encourage responsible re-introduction of practices previously condemned in residential and mixed uses neighborhoods. For example, many U.S. communities are passing ordinances to reintroduce chicken and bee keeping. Though trends to date indicate that many professional planners are generally disinclined to reintroduce previously condemned, 'organic' urban practices to the American city, such local ordinances, which have been called 'honey and eggs' ordinances, permitting specific urban agriculture activities in approved areas have gained popularity in recent years (Brinkley & Vitiello, 2014). Is it possible to use community ordinances to approve ecosan system installations or small-scale composting facilities more easily in areas where they are currently discouraged? How could such local ordinances be designed and trialed to encourage responsible piloting of more sustainable sanitation systems?

Master Plans and Zoning: Master plans that set long-term goals for phasing out water-based and input-intensive infrastructures while phasing in sustainable alternatives could help communities transition to more affordable and resilient sanitation systems over time. When crafting Master Plans, planners can estimate the life expectancy of existing wastewater infrastructures, including both centralized piping and treatment facilities as well as decentralized septic systems. Based on projected degradation and failure rates, it is possible to design transition timelines to slowly introduce a range of ecological sanitation approaches as individual systems fail and require replacement. Phased and incremental introduction schemes can ease and guide a responsible and gradual transition, allowing local attitudes and communal management structures to grow and mature over time.

'Reach' or 'stretch' codes can be used to phase in innovative practices safely. The experience of the REI project reflects this approach, where relationships among project administrators, regulators, farmers, and residual transportation specialists were able to initiate and expand gradually over several years. In contrast, the Falmouth program called for a relatively rapid and top-down designation of a communal residuals management scheme, which may explain why it failed to develop. Strategic zoning of Eco-Districts or use of bylaws requiring low-impact development (LID) practices could incorporate language to encourage eco-toilet use where appropriate. Areas with the need or desire to limit water, material and energy consumption levels, to control development rates (sewer installations typically accelerate uncontrolled development patterns), to encourage infill development (siting for septic systems requires inclusion of a leach field), or to preserve established settlement patterns or specific building sites may benefit from such local planning strategies.

The need to limit development rates, encourage infill, and reduce infrastructure costs characterizes many aging, rural and peri-urban villages with low tax bases and a desire for economic revitalization. Some planners have begun to identify the potential for decentralized ecosan technologies to meet the needs of these communities by revitalizing sanitary services without encouraging uncontrolled development.

Opportunities in Public Parks and Historic Preservation: Another application of ecosan systems has attracted some planners' attention: use in parks and historic buildings. Ecosan systems are often able to serve locations where conventional sanitation installations are either impossible due to topographical or physical constraints, or impractical due to high connection and maintenance costs. For these reasons, eco-toilets can present excellent solutions for rural public restrooms and for inclusion in historic preservation sites with delicate foundations or other site limitations. Figure 14 describes an ecosan installation at the Barnes Camp Visitors Center in Vermont, a case that exemplifies these principles.

The example of Barnes Camp points to opportunities in public parks and open space sites across the country. In fact, several park systems in the U.S.

Figure 14: Ecosan and Historical Preservation: Barnes Camp in Stowe, Vermont

The Barnes Camp Visitors Center is an historic logging cabin in Stowe, Vermont, that has been converted into a public visitors center due to its convenient location at the entrance to a popular state park. The preservation and re-purposing of the historic site was made possible in part due to an alternative sanitation solution devised for the site after it was confirmed that the center could not support a water-based sanitation system.

Planner Seth Jensen of the Lamoille County Planning Commission proposed and implemented plans to equip the site with UDDT ecosan systems. The site is now served by two handicap-accessible eco-toilets designed and maintained by the Clivus Multrum company, who has a partnership with the Vermont State Parks system to support several rural sites with ecosan system installation and maintenance. Named *Project of the Year* for 2015 by the Vermont Planners Association (VPA), the Barnes Camp restoration project has incorporated planning values for historic preservation, open space access, growth management, and sustainability.

already offer eco-toilets for visitor use. Some park systems have established formal and long-term partnerships with private companies that manage individual sites, such as the partnership between the Vermont State Parks system and the Clivus Multrum company. States with these established relationships and management schemes are well positioned to expand these practices within and beyond park settings, and can provide valuable lessons to other states and groups about their experiences. As demonstrated by the principal role that planner Seth Jensen played to restore and equip Barnes Camp with eco-toilet systems, it is possible for professional planners to take a leading role in encouraging and facilitating these reforms in their communities.

Frameworks: Planning frameworks that are potentially useful in understanding how planners can support ecosan campaigns in the U.S. include at least four frameworks: food systems planning, advocacy planning, insurgent planning and public participation. Food systems planning, a recently popular specialization within the planning field, takes a holistic approach to planning and problem solving across areas of public health, agriculture, and processing, distribution and commercialization of food (APA, 2007). A recent planning thesis concluded that insufficient attention has been paid to composting and other nutrient reclamation practices in food systems planning work to date (Thompson, 2012). UD ecosan systems' ability to efficiently recycle nutrients as a locally sourced agricultural input could merit study under this framework.

More theoretically based approaches of advocacy and insurgent planning frameworks can also be applied to sanitation reform. Recognition of planners' obligation to advocate for solutions to communities' greatest social and physical needs underpins the ideas of advocacy planning (Davidoff, 1965). A prioritization of bottom-up problem solving in contrast to rational planning models characterizes community-based insurgent planning approaches. For example, the proposed 'rebel charge' of Vermont planners (see Figure 15) to focus planning discussions on alternative sanitation solutions in the state resonates with some values of insurgent planning as described by John Friedmann (2011) and Faranak Miraftab (2009). As planners and communities alike try to understand

Figure 15: Ecosan and Village Revitalization: A 'Rebel Charge' by VT Planners

Conversations with Vermont planners confirm chronic sanitary infrastructure decline across the state. Planner Sarah Hadd, voted *Vermont Planner of the Year* by the VPA in 2014, laments a lack of attention formally directed toward issues of failing wastewater systems statewide. Hadd explains that though planners increasingly deal with sanitation improvements individually in their communities, there is no professional task group currently dedicated to these concerns.

Recognizing a need to focus planners' attentions on sanitary reform in the state, Hadd reports that a 'rebel charge' of planners is proposing to establish a working group with the VPA to discuss these problems, despite the fact that wastewater issues do not usually receive such specialized attention within the association.

Further south in the state, Chris Campany, director of the Windham County Commission, is searching for sanitary options for small towns with ailing infrastructures and whose economic growth and vitality are hindered by lack of sanitation. According to Campany, community ecosan systems could potentially meet needs to revitalize these communities.

These Vermont planners and others are recognizing a statewide need to reform sanitation practices to become more affordable and to better serve their communities in the long run. Perhaps a planners' 'rebel charge' will be able to consolidate unprecedented collective action across the state.

emergent trends in sanitary reform, these frameworks may provide enlightening orientations.

5.3.2 Communities Before Planners

Professional planners have the chance to proactively support sanitary reforms in the U.S. in coming years, yet they do not hold the principal role in mobilizing sustainable sanitation campaigns. The pilot initiatives that have arisen in the U.S. in recent years represent the work of average citizens and broad community support bases. The power of communities to realize greater innovation and self-determination in local sanitation planning is becoming more evident. Planners and other professionals who wish to support innovative sanitation planning should remember that interest in ecosan systems and other alternatives must originate from a popular community base, since top-down ecosan projects risk serious complications and failure.

Communities may choose to formalize ecosan interests as municipal public services, as has been trialed in Falmouth. In fact, it is likely that the municipal model trialed by Falmouth will be interpreted as the most viable model for replication in U.S. communities. Yet, as the Falmouth case demonstrates, serious challenges to this traditional governance approach include the political contention inherent in the allocation public funds, bureaucracy and technocracy trends in sanitation project management, and the task of designing incremental transition plans. In general, public programs represent an advantage of stable funding and legitimacy; yet have limited flexibility to adapt to changing opportunities or user needs.

On the other hand, the non-profit approach adopted by REI exemplifies opposite characteristics of high programmatic flexibility with the drawback of potential financial instability. It is clear from REI's example, however, that non-profit organizations can play significant roles in sanitation policy changes in coming years. Several campaigns already underway in the U.S. to reform sanitary codes and regulations have been sustained by non-profit work, such as the progress made by greywater action groups in the Southwest and code reform teams based in Oregon.

Regardless of what formalization process citizens choose to pursue, the community bases of ecosan proposals must remain at the center of projects moving forward. When reflecting on the role of average citizens and professional planners in these processes, I think of Brooks' suggestion that *planning* is not so much a profession as it is a "loose confederation of shared interests and concerns" held by some for the future well being of their community (Brooks, 1993, p. 143). This interpretation of planning better recognizes the contributions of average citizens and community-based movements in improving towns and cities through engagement and design processes. Large-scale ecosan pilot projects have embodied community-based planning processes to date and future initiatives will do well to continue this legacy.

5.4 Closing

This chapter has provided an overview of initial lessons to be gleaned from ongoing pilot ecosan projects in the U.S. Findings suggest that green communities with sanitary needs and agricultural land uses provide opportunities for the implementation of ecosan pilot programs. Future projects are likely to encounter barriers related to institutional bias against innovation and mixed user receptivity to ecosan adoption, but strategic program decisions can help overcome these challenges. Professional planners can adopt positive or negative outlooks on sanitary reforms, but citizens will ultimately have the last word in planning local sanitation solutions. The final chapter summarizes broad recommendations for community-scale ecosan implementation in the U.S., as well as directions for future research. Final reflections close the thesis.

CHAPTER 6

RECOMMENDATIONS & CONCLUSIONS

"Citizenship, like justice, like hygiene…"
- Patrick Geddes, *Cities in Evolution* (1915)

6.1 Recommendations for Community-Scale Ecosan Planning in the U.S.

Awareness of the precarious state of existing sanitation infrastructures in the U.S. and municipalities' inability to afford the repairs and expansions necessary to sustain them is on the rise nationally. The need to explore lower-cost alternatives has placed community-scale innovative and alternative sanitations systems on the table for consideration in the U.S., but unfamiliarity with these systems and outstanding questions about their scalability raises doubts about their potential viability in U.S. communities.

Despite these uncertainties, current trends indicate that community ecosan is likely to be piloted and tested further in coming years. Existing experiences must be scrutinized to deliver insights about how large-scale implementations function in the North American context and to identify best practices for trialing these approaches. Recent experiences in U.S. community ecosan indicate that future projects are most likely to be effective if the following conditions and practices are considered:

1. Proposals for community-scale ecosan implementation should arise from a popular community base. Transparent project O&M should aim to sustain local leadership and respond to participant input.
2. Where possible, ecosan pilot projects should be introduced proactively and should offer incremental transition options for adoption that is complementary to ongoing conventional sanitation practices. Proponents

should avoid framing ecosan as a universal sanitation solution for all populations and locations.

3. Projects should plan for comprehensive residuals management, engage in research activities if applicable, pursue local and state regulatory and legislative reforms, and network with allied groups at various scales to coordinate broader reforms.
4. Professionals such as planners, regulators, engineers, and public health officials should be receptive to sanitation reforms proposed by communities. While using professional tools to enhance understanding and rigor of pilot programs, they must ultimately allow communities to make their own sanitation decisions.

If projects manage to combine strategies and principles such as these, it is possible they stand a better chance of positive reception, effectiveness and replicability. Understandings of best practices for community ecosan will continue to expand as more projects are pursued and studied critically. Over time lessons from additional experiences will hone these initial recommendations and offer new insights as well.

6.2 Future Research

Many of the findings presented in this report echo conclusions of existing ecosan studies. Contextualization of this study in the previously unexamined territory of the U.S., though, has shed light on knowledge gaps specific to this national context as well as more general gaps in the literature.

Firstly, study of the pilot programs has confirmed that project O&M strategies can have significant, if not the most significant, impact on ecosan project performance over time. However, this aspect of ecosan programs is chronically understudied. In the absence of structured ways to understand O&M impacts on ecosan program performance, a tendency toward linking program failures to technological or user receptivity factors instead of programming decisions abounds (Fox, 2015). There is a need for standardized ways to record and assess O&M practices and link specific practices to general strengths and limitations of ecosan programs. For example, *What specific management-, participant relations-, incentive packaging- and regulatory practices are tied to program effectiveness, and what practices are linked to program weaknesses?*

From this line of thinking arises another topic that has yet to be unpacked in the ecosan literature: what do we mean when we regard an ecosan program as effective or successful? What accomplishments and other indicators should be used to gauge ecosan success in the U.S. context? No comprehensive framework for comparing the performance of community ecosan systems against those of conventional sanitation approaches has been outlined. Such a model would have to include indicators for relative costs, user acceptability, resiliency scores, energy and material input levels, chemical and nutrient pollution rates, pathogen and CEC remediation, and beneficial product generation by the systems. This point is inspired by recent calls for better performance monitoring of green infrastructure installations to understand if they actually meet the goals they claim to achieve. Insofar as ecosan installations can be considered green infrastructures, *how can ecosan systems be monitored to assess overall performance relative to other sanitation technologies*?

Studies already underway to better understand the fate of PPCPs and other CECs in human urine and feces residuals must continue and expand. Experts across a broad range of disciplines can be tapped to lend their analytic frames to the topic of sanitation reform and community ecosan implementation. The fields of soil science, environmental psychology, public policy, and sociology, to name just a few, have broad knowledge bases that can be applied to better understand options moving forward in the planning of sanitation systems in the U.S.

Experts of various disciplines may expand upon many of the introductory findings presented here. Due to scope limitations of this thesis, findings about institutional barriers such as regulations, formalization pathways, and potential funding sources for ecosan systems are still introductory and should be examined further. Some of the literature argues that new institutional arrangements are necessary for ecosan to be accepted and popularized (Ferguson, Brown, Frantzeskaki, de Haan, & Deletic, 2013; Winblad & Simpson-Hébert, 2004). *What would such institutional (re)arrangements look like in the U.S.? What regulatory language and frameworks best promote innovation while also safeguarding public health? What scale of regulation (local, state, federal) is most appropriate to oversee various aspects of ecosan implementation? What pathways for ecosan project formalization and funding are most effective, resilient, and replicable across the U.S.?*

This thesis also represents a broad and introductory study of demographic factors linked to ecosan interest and receptivity in the U.S. Though this report's conclusions point to important broad trends, deeper and more focused investigations into the socio-cultural characteristics linked to ecosan adoption are merited. Both general population attributes in communities where large-scale ecosan is accepted and specific participant characteristics should be studied further. For example, a particularly interesting finding of this thesis highlights the fairly narrow demographic appeal of community UD ecosan systems in the U.S. *What are the implications of this narrow appeal for future applications or expansions of ecosan practices? In general, how is fringe, or 'green' technology adoption related to issues of social class, education attainment, and general affluence and stability? How will ecosan proponents deal with the limited appeal of this technology for social groups other than their own?* These are just some of the many fruitful directions that additional research can take.

6.3 Final Thoughts

Though the future acceptance and proliferation of community-scale ecosan systems in the U.S. is uncertain, the need to improve dominant wastewater sanitation practices to become more affordable, efficient and sustainable is undeniable.

While this thesis has heretofore explored the role of average citizens and professional planners in the process to reform U.S. sanitation, it has yet to implicate the entity that has historically exercised the greatest force in U.S. sanitation planning: the federal government. As Melosi (2008) demonstrates, the federal government played a central role in expanding universal wastewater sanitation coverage in the 20st century through sweeping regulatory and fiscal legislation. How will the federal government contribute to sanitary improvements in the coming years, though? Communities in need of sanitation expansion or updates are realizing that federal grants that previously supported municipalities in attaining WWTF infrastructure no longer exist. Some states offer loans for wastewater infrastructure works to make up for this funding gap, but municipal budgets are still unable to bear full costs in many cases (Melosi, 2008).

The legacy of the federal government's critical role in U.S. sanitation planning is important to remember moving forward. While the communal self-determination embodied in emergent ecosan projects is admirable and celebrated on the one hand, it also reflects the outcome of a larger process of devolution of governance responsibilities and defunding of public infrastructure projects since the 1980s. These public policy changes have created the difficult situation many towns are facing, with crumbling sanitary infrastructures and little to no fiscal support to improve them. Are U.S. communities on their own to solve these sanitary problems? If they are, then interest in lower-cost, decentralized sanitation systems such as community-scale ecosan and other small-scale solutions can only expand in the coming decades.

Today the U.S. finds itself at a sanitary impasse, and future directions for comprehensive sanitation planning in the country are unclear. Only time will tell how receptive different U.S. communities will be to emergent proposals for ecosan and other alternative sanitation approaches. The roles that citizens, professional planners, and various levels of government will play in reforming conventional sanitation practices in the U.S. will certainly be mixed and innovative, however. Without a doubt, sanitation planning will have to evolve to meet the demands of communities and their changing visions of the Sanitary City.

APPENDIX A

DRAFT IAPMO GREEN SUPPLMENT PLUMBING CODES

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Recode Draft Plumbing Code for Composting and Urine Diversion Toilets

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Justification

Introduction
Water scarcity and pollution concerns are driving the adoption of composting and urine diversion toilet systems in the US and abroad. In the US, these systems have been treated unevenly by a patchwork of regulations in Health, Onsite Sanitation, and Building Code departments because they do not fit neatly into categories designed to guarantee safe sanitary drainage systems. It is the opinion of this code group that composting and urine diversion toilets are at a turning point, mature enough to build sound regulation around while also being a site of active research and development. Our intent is therefore to create code language that provides for strict protections on public health while also encouraging the growth of domestic industry and innovation in composting and urine diversion systems.

Performance Coding
As far as is possible, this code is a performance code, meaning that it does not judge systems on what they look like, but rather on the operational conditions within. For this code, that means integrating field testing into the evaluations of new systems and providing prescriptive best practice guidance in conjunction with performance requirements.

Protections for Public & Homeowner Health
This code is a combination of performance testing and prescriptive guidelines for ventilation, screening, and retention time of compost and diverted urine to create easy-to-follow and inspect requirements that protect public health even in the event of system failure and poor owner maintenance. Our code mandates that unsaturated aerobic decomposition conditions be maintained, that temperature stay within the range of beneficial decomposing organisms, and that decomposition occur for at least one year, outside the survival time of pathogens. In the event of maintenance failure, watertightness, screening, and ventilation requirements prevent both public health threats from arising and major inconvenience in the home.

Environmental Protection:
Urine diversion can reduce nitrogen in domestic wastewater by 80%, and Composting Toilet Systems can reduce household nitrogen by close to 90%, both at installed costs of $3-6,000. This is a higher performance than Alternative Treatment Technologies (ATTs) and sand filters currently required in many jurisdictions with surface and groundwater concerns, and at a fraction of the cost. This code brings new, lower cost options for environmental protection to homeowners.

Innovation:
This code enables the installation of innovative technologies by creating a code with clear inspection points to safeguard public health even in the event of the failure of new or experimental designs. The output of the installations of a composting toilet system are subjected to biological field testing and verification to assure performance. Our hope is that this code will help launch a vigorous domestic industry in composting toilets and urine diversion systems.

Composting Toilet System Definitions

Commode. The composting toilet fixture for collecting, containing, or transporting excreta to the compost processor.

Compost Additives. Any material such as sawdust, wood shavings, and other compostable material added to the commode or compost processor to maintain operational conditions within the composting toilet system.

Composting Toilet System. A system designed to safely collect and process excreta and compost additives into humus through aerobic decomposition.

Compost Processor. The site of aerobic decomposition transforming excreta and compost additives into humus.

Desiccation. The process of dehydrating excreta or leachate.

Diverted Urine. Urine that is collected and has not made contact with feces.

Excreta. Includes but is not limited to urine, feces, menses, toilet paper, and other human body emissions and biodegradable cleaning products.

Humus. The biologically decomposed, soil-like output of the compost processor.

Leachate. Liquid draining from the compost processor.

Owner's Manual. A manual provided to the owner of a composting toilet system containing instructions for all management aspects of that system.

Secondary Composting. Additional retention and continued decomposition of humus removed from compost processors in order to meet a safe retention time.

Site-Built. Constructed at the site of use.

Transfer. The controlled transfer of excreta or partially processed humus between commode and composting processor or between multi-stage composting processors.

Urine Diversion. Separation of urine from other excreta that occurs at the commode.

Vectors. An organism that has the potential to transmit disease.

Composting Toilet Systems

General. The provisions of this section shall apply to the design, construction, performance, alteration, and repair of composting toilet and urine diversion systems.

Design and Construction Requirements. Composting toilets, composting toilet systems, and urine diversion systems shall meet the design, construction, and performance requirements of either Listed Composting Toilets and Composting Toilets Systems or Alternative Design Systems.

Listed Composting Toilets and Composting Toilet Systems. Composting toilets and composting toilet systems shall be listed to NSF/ANSI Standard 41.

Alternative Design Systems. Composting toilet and urine diversion systems for residential and commercial applications complying with the provisions of this section shall be permitted where approved by the Authority Having Jurisdiction.

System Materials and Components. Pipe, pipe fittings, traps, fixtures, material, and devices used in composting toilet and urine diversion systems that are expected to contact leachate or diverted urine shall be listed or labeled (third-party certified) by a listing agency (accredited conformity assessment body), unless otherwise approved by the Authority Having Jurisdiction. Materials and components shall comply to approved applicable recognized standards referenced in this supplement and the plumbing code, and shall be free from defects. Unless otherwise provided for in this supplement, materials, fixtures, or devices used or entering into the construction of plumbing systems, or parts thereof, shall be submitted to the Authority Having Jurisdiction for approval.

System Design. Composting toilet and urine diversion systems complying with this code shall be designed by a person registered or licensed to perform plumbing design work or who demonstrates competency to design composting toilet and urine diversion systems.

Permit. It shall be unlawful for any person to construct, install, alter, or cause to be constructed, installed, or altered any composting toilet and urine diversion system in a building or on a premise without first obtaining a permit to do such work from the Authority Having Jurisdiction.

Maintenance and Inspection. Composting toilet and urine diversion systems and components shall be maintained and inspected in accordance with the following Sections Maintenance and Responsibility, Operation, and Inspection.

Maintenance Responsibility. The required maintenance and inspection of composting toilet and urine diversion systems shall be the responsibility of the property owner, unless otherwise required by the Authority Having Jurisdiction. The property owner is responsible for retaining test result records in accordance with the Section titled 'Humus' and making them available to the Authority Having Jurisdiction upon request. Upon transfer of property or tenancy, all test records shall be transferred and humus shall be re-tested after its first treatment period and a record retained.

Operation. Composting toilet and urine diversion systems shall be operated in a safe and sanitary condition in accordance with the owner's manual in accordance with the Section Operation and Maintenance Manual.

Inspection. In the event of a nuisance complaint or documented system failure, the composting toilet and urine diversion system shall be made available for inspection and the owner or owner's agent shall conduct sufficient repairs or alterations to the composting toilet system. At the owner's expense, the Authority Having Jurisdiction shall be permitted to request results of all laboratory testing and require new tests in accordance with Section Testing, following repairs to alleviate dangerous or unsanitary conditions.

Operation and Maintenance Manual. An owner's manual shall present clear instructions for maintenance and be transferred to the new owner upon transfer of property or tenancy. The owner's manual shall include:

1. Schedule for addition of necessary compost additives.
2. Source or provider of necessary compost additives. Source may be on-site.
3. Schedule and instructions for all regular maintenance tasks.
4. Expected input of and capacity for excreta and compost additives to compost toilet system specifying loading of commode(s) and compost processor(s).
5. Plan for container transfer and cleaning where transfer is used.
6. Expected schedule for removing humus from composting processors and where used secondary composting bins.

7. Plan for on-site disposal of humus or professional removal.
8. Plan for managing leachate.
9. Plan for microbial testing in accordance with Section on Humus.

Composting Toilet System Design Requirements. The design and installation of composting toilet systems shall be in accordance with Section Durability through Section Humus Removal.

Durability. All components expected to contact excreta or leachate shall be constructed of corrosion-resistant material such as stainless steel or durable polymers (ABS, PVC Schedule 40, Polypropylene, High-density polyethylene, Fiber-reinforced polyester, or material of equivalent durability). Concrete in contact with excreta or leachate shall meet requirements of Section Concrete Construction.

Concrete Construction. Concrete construction shall be reinforced, watertight and able to withstand loading weight. Where drainage is required, the processor floor shall be sloped not less than ¼-inch per foot. The flange of each sub-drain shall be set level.

Commodes.

Structure. Commodes shall be designed to support users.

Odor. Commode design or use shall mitigate the infiltration of odors into the building during normal operation and in the event of temporary power failure.

Contact. Commodes shall transport excreta into the compost processor or contain excreta for transfer as designed according to the owner's manual.

Vectors. Commodes shall limit vectors and prevent human contact except for regular maintenance as designed according to the owner's manual.

Compost Processors. Compost processors shall be designed in accordance with Section Leachate through Sizing and shall maintain unsaturated aerobic composting conditions within the compost mass, through the drainage, absorption, or desiccation of leachate, and aeration of the processor.

Leachate. Leachate shall be collected for removal or recirculation within the processor, evaporated, or drained to an approved plumbing drainage system or other location approved by the Authority Having Jurisdiction. Leachate storage tanks shall be constructed and installed in accordance Section Venting through Openings.

Venting. Leachate storage tanks shall be vented as required for pressure equalization. When required, vents shall be installed on leachate storage tanks and shall extend from the top of the tank. Storage tank vents shall be permitted to connect to the plumbing venting system 6 inches above the flood level rim of the highest fixture. Vents extending to the outdoor shall terminate no less than 12-inches above grade. The vent terminal shall be directed downward and covered with a 3/32 inch mesh screen to prevent the entry of vermin and insects.

Vent Size. Pressure equalization vents that prevent nitrogen loss by the use of restrictions, or of piping or tubing that is less than the minimum pipe diameter required in the plumbing code shall be approved by the Authority Having Jurisdiction.

Overflow. Where storage tank overflows are installed they shall be connected to the plumbing drainage system.

Backwater Valve. Storage tank overflows shall be provided with a backwater valve or check valve at the point of connection to the plumbing drainage system when connected to a public sewer system. The backwater valve shall be accessible for inspections and maintenance.

Construction. Leachate storage tanks shall be constructed of polyethylene terephthalate (PET), polyethylene napthalate (PEN), polyamide (Nylon) or a blend of PET, PEN, ethyl vinyl alcohol (EVOH), Nylon, HDPE, or other tanks listed or certified to US 49 CFR Section 178.274 "Specifications for UN portable tanks."

Above Grade. Above grade storage tanks shall not be permitted where subject to freezing conditions, or shall be provided with an adequate means of freeze protection. The above grade leachate storage tank shall be provided with a high-water alarm. The alarm shall report when 80 percent volume is reached.

Below Grade. Leachate storage tanks installed below grade shall be structurally designed to withstand all anticipated earth or other loads. Tank covers shall be capable of supporting an earth load of not less than 300 pounds per square foot (lb/ft^2) (1465 kg/m^2) when the tank is designed for underground installation. Below grade leachate tanks installed underground shall be provided with manholes. The manhole opening shall be a minimum diameter of 20 inches (508 mm) and located a minimum of 4 inches (102 mm) above the surrounding grade. The surrounding grade shall be sloped away from the manhole. Underground tanks shall be ballasted, anchored, or otherwise secured, to prevent the tank from floating out of the ground when empty. The combined weight of the tank and hold down system should meet or exceed the buoyancy force of the tank. The below grade leachate storage tank level shall be provided with a high-water alarm.

Marking. Where openings are provided to allow a person to enter the tank, the opening shall be marked with the following words: "DANGER—CONFINED SPACE."

Openings. All openings shall be covered and secured to prevent tampering. Openings shall be screened or covered to prevent rodent infiltration and be protected against unauthorized human entry.

Vectors. The compost processor shall be designed and installed to limit vector access through management as required in the owner's manual.

Transfer. Where unfinished excreta or diverted urine is transferred between processors or from commode to processor, transfer and cleaning of containers and provisions for limiting user exposure shall be according to the owner's manual.

Watertightness. Processors shall be constructed of watertight material in accordance with Section Durability.

Rodent proofing. The compost processor shall be protected to prevent the entrance of insects, birds, or rodents. No unsecured opening other than vents, drainage, or commode may exceed ½-inch in the least dimension.

Active Conditions. The compost processor or processors shall be sized to compost excreta for a minimum of one year of biologically active conditions. Biologically active conditions are at or above a daily average of 42°F (6°C).
Exception: Systems with shorter retention shall be permitted where either,
(a) humus from the compost processor has been tested according to Section Humus and there is a secondary composting stage where humus is retained in a well maintained compost bin or other facility designated for the exclusive purpose of containing humus removed from the compost processor, or
(b) humus is removed off site for processing or disposal at an approved facility.

Secondary Composting. Humus transferred to secondary composting shall first be tested according to the Humus section. Secondary composting shall be labeled and protected from human contact. Contact with precipitation and surface waters is prohibited.

Ventilation. Negative ventilation between the commode and compost processor shall be provided when the compost processor is connected directly to the commode without a trap. Commodes that are not connected to the compost processor do not require a vent.

Vent Terminals. Vent stacks shall terminate exterior the building as required by the plumbing or mechanical code.

Sizing. The compost processor shall be sized to accommodate the maximum daily adult usage as specified by the manufactures published ratings. Site built compost processors shall be sized to hold a minimum of 10 gallons of material per person per year while allowing for the removal of the humus, or as specified by the system designer.

Testing. Composting toilet systems shall be tested in accordance with the following sections on Compost Processors and Humus.

Compost Processors. Compost processors shall be tested for water tightness by filling the system to the maximum designed liquid storage capacity of the unit for a duration of 24 hours.

Humus. The owner or owner's agent of the composting toilet system shall verify user's compliance with the manufacturer's maintenance and operation manual in accordance with the Humus Section by submitting a sample of the humus from the first treatment period after a minimum of one year of biologically active conditions to a certified laboratory before removal of humus from the composting processor. Where multiple compost processors are used, the humus sample shall be removed from the last compost processor. The sample collection shall be tested in accordance with EPA/625/R-92/013, Appendix F, Section 1.2. Humus shall not have a moisture content exceeding 75% by weight, and shall not exceed 200 fecal coliforms/gram.

Humus Removal. Humus shall be removed according to the owner's manual. Humus from the compost processor shall be permitted to be used around ornamental shrubs, flowers, trees, or fruit trees and shall be mixed with soil or mulch and covered with 3 inches of cover material. Depositing humus from any composting toilet system around any edible vegetable or vegetation shall be prohibited.

Urine Diversion Systems

Urine Diversion System Design Requirements. The design and installation of urine diversion systems shall be in accordance with Section Purpose through Section Treatment, Reuse, and Disposal.

Purpose. The purpose of this section is to enable the installation of urine diversion and collection systems to improve the function of composting toilet systems and prevent nutrient pollution of ground and surface waters.

Material Requirements. Material used for urine diversion shall be stainless steel or non-metallic pipe. Concrete piping is prohibited.

Identification. All urine diversion piping shall be identified.

Change of Direction. Changes in direction of urine diversion piping shall be made by a long-sweep 90 degree fitting or other approved fittings of equivalent sweep.

Sizing. Pipe sizes shall be in accordance with the plumbing code. Each urine diversion fixture shall be rated as one drainage fixture unit. Piping or tubing for urine diversion that is less than the minimum pipe diameter required in the plumbing code shall be approved by the Authority Having Jurisdiction.

Traps. Fixtures discharging into urine diversion piping connected to the plumbing drainage system shall be trapped and vented according to the plumbing code.

Grade of Horizontal Piping. Urine diversion piping shall be installed at a minimum grade of ½-inch per foot, or 4 percent toward the point of disposal.

Cleanouts. A cleanout shall be provided at the upper terminal of each drain line, every 50 feet and at an aggregate horizontal change of direction exceeding 135 degrees.

Venting. Commode fixtures without traps that require ventilation shall be connected to either a dry toilet ventilation stack or a urine diversion ventilation stack. Nonwater urinals used as urine diversion systems shall be connected to a dry toilet ventilation stack or a urine diversion ventilation stack.

Discharge. A urine-diversion system shall be diverted to a storage tank or discharge to an approved plumbing drainage system.

Urine Diverting Composting Toilet Systems

Urine Storage Tanks. Urine storage tanks shall be constructed and installed in accordance with the following: Section Venting through Openings.

Venting. Urine storage tanks shall be vented as required for pressure equalization. When required, vents shall be installed on urine storage tanks and shall extend from the top of the tank. Storage tank vents shall be permitted to connect to the plumbing venting system 6 inches above the flood level rim of the highest fixture. Vents extending to the outdoor shall terminate no less than 12-inches above grade. The vent terminal shall be directed downward and covered with a 3/32 inch mesh screen to prevent the entry of vermin and insects.

Vent Size. Pressure equalization vents that prevent nitrogen loss by the use of restrictions, or of piping or tubing that is less than the minimum pipe diameter required in the plumbing code shall be approved by the Authority Having Jurisdiction.

Traps. Urine storage tanks shall prevent odors and nitrogen loss from the tank inlet by means of a P-trap, mechanical trap, submerged inlet piping, or other means approved by the Authority Having Jurisdiction. Submerged inlet piping shall remain submerged during use and after pumpout. Exception: Tanks of five gallons or less connected to fixtures with active ventilation or having an integrated seal.

Overflow. Where storage tank overflows are installed they shall be connected to the plumbing drainage system.

Backwater Valve. Storage tank overflows shall be provided with a backwater valve or check valve at the point of connection to the plumbing drainage system when connected to a public sewer system. The backwater valve shall be accessible for inspections and maintenance.

Construction. Urine storage tanks shall be constructed of polyethylene terephthalate (PET), polyethylene napthalate (PEN), polyamide (Nylon) or a blend of PET, PEN, ethyl vinyl alcohol (EVOH), Nylon, HDPE, or other tanks listed or certified to US 49 CFR Section 178.274 "Specifications for UN portable tanks."

Above Grade. Above grade storage tanks shall not be permitted where subject to freezing conditions, or shall be provided with an adequate means of freeze protection. The above grade urine storage tank shall be provided with a high-water alarm. The alarm shall report when 80 percent volume is reached.

Below Grade. Urine storage tanks installed below grade shall be structurally designed to withstand all anticipated earth or other loads. Tank covers shall be capable of supporting an earth load of not less than 300 pounds per square foot (lb/ft^2) (1465 kg/m^2) when the tank is designed for underground installation. Below grade urine tanks installed underground shall be provided with manholes. The manhole opening shall be a minimum diameter of 20 inches (508 mm) and located a minimum of 4 inches (102 mm) above the surrounding grade. The surrounding grade shall be sloped away from the manhole. Underground tanks shall be ballasted, anchored, or otherwise secured, to prevent the tank from floating out of the ground when empty. The combined weight of the tank and hold down system should meet or exceed the buoyancy force of the tank. The below grade urine storage tank level shall be provided with a high-water alarm.

Marking. Where openings are provided to allow a person to enter the tank, the opening shall be marked with the following words: "DANGER—CONFINED SPACE."

Openings. All openings shall be covered and secured to prevent tampering. Openings shall be screened or covered to prevent rodent infiltration and be protected against unauthorized human entry.

Maintenance Plan. Every urine diversion system shall have a maintenance plan that includes both a pumpout schedule and contract, or an onsite discharge plan. The maintenance plan shall also include a pipe cleaning schedule.

Treatment, Reuse, and Disposal. Where urine is to be reused onsite, a treatment method for sanitization shall be included in the owner's manual. Approved methods of treatment shall include:

1. Retention without addition for six months before usage. Two or more holding tanks shall be required for retention,
2. Application to the compost processor,
3. Pasteurization to 158° F. (70°C) for thirty minutes, or
4. Other method approved by the Authority Having Jurisdiction.

Appendix

Note: All images are conceptual and are not construction diagrams.

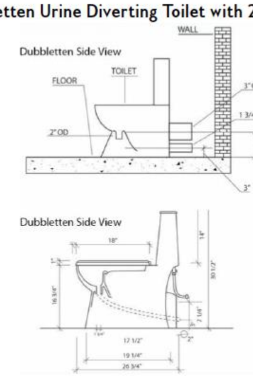
Barrel Composting Toilet & Urine Diverter with 1/4" hose

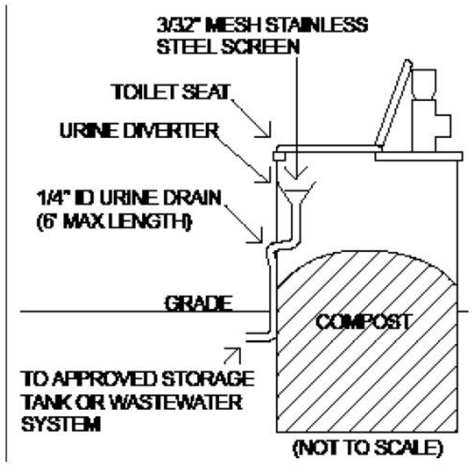
Design by David Omick.
Urine also contains high concentrations of dissolved minerals that form deposits on the inside of ordinary drain pipes, eventually clogging them. The small diameter pipe requires only a 1/2 cup of water following each use to thoroughly rinse the entire inside surface of the pipe thus preventing mineral buildup. Complete rinsing reduces the chance of struvite forming.

A small diameter drain also helps to prevent cockroaches and other disease vectors from entering or leaving the toilet through the drain.

Automotive fuel hose makes a good urine drain hose as it's durable, non-corrosive and resistant to kinking.

Dubbletten Urine Diverting Toilet with 2" hose





EcoFlush Urine Diverting Flush Toilet with 1" hose

Advantages: lowers water consumption by approximately 70-90% of a conventional flush toilet which lowers volume for collection system. Large flush is 2.5 L, small flush is 0.3-0.5 L.

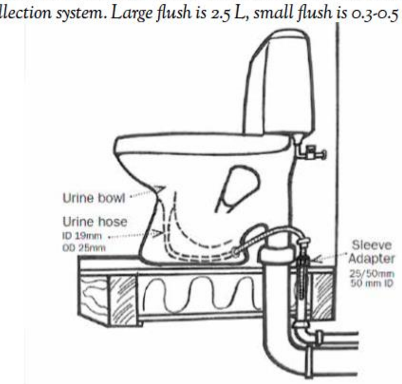


TABLE 1 TYPICAL PATHOGEN SURVIVAL TIMES AT 20 TO 30°C IN VARIOUS ENVIRONMENTS

	Survival Time, Days		
Pathogen	**Fresh Water and Wastewater**	**Crops**	**Soil**
Bacteria			
Fecal coliforms[a]	< 60 but usually < 30	< 30 but usually < 15	< 120 but usually < 50
Salmonella (spp.)[a]	< 60 but usually < 30	< 30 but usually < 15	< 120 but usually < 50
Shigella[a]	< 30 but usually < 10	< 10 but usually < 5	< 120 but usually < 50
Vibrio cholerae[b]	< 30 but usually < 10	< 5 but usually < 2	< 120 but usually < 50
Protozoa			
E. histolytica cysts	< 30 but usually < 15	< 10 but usually < 2	< 20 but usually < 10
Helminths			
A. lumbricoides eggs	Many months	< 60 but usually < 30	< Many months
Viruses[a]			
Enteroviruses[c]	< 120 but usually < 50	< 60 but usually < 15	< 100 but usually < 20

a In seawater, viral survival is less and bacterial survival is very much less than in fresh water.
b *V. cholerae* survival in aqueous environments is a subject of current uncertainty.
c Includes polio, echo, and coxsackie viruses.

Source: Adapted from: Crites and Tchobanoglous, 1998.

APPENDIX B

RICH EARTH INSTITUTE PHOTO DOCUMENTATION

Section 1: Functional Groups: User Interface & Collection

Upper left: Blue Separett® insert used for urine source separation. Source: aldatu.eu; Middle left: Urinal designed and made by REI. Source: photo by C. Bryars; Bottom left: Nun's cap toilet insert. Source: quickmedical.com; Right: Urine-only porta-potty. Source: photo by C. Bryars.

Section 2: Functional Groups: Storage & Conveyance

Left: Five-gallon container delivered to Drop-Off Depot by urine donor. Source: Rich Earth Institute; Center: Self-Service Urine Pump at Drop-Off Depot. Source: photo by C. Bryars: Right: Drop-Off Depot located at REI Headquarters. Source: photo by C. Bryars.

Section 3: Functional Groups: Conveyance & Use

Above: Horse-drawn urine applicator; Bottom left: Seth of Best Septic pumps holding tanks at a Drop-Off Depot. Source: photo by Rich Earth Institute; Bottom right: Hand-held wand urine applicator. Source: Photo by Rich Earth Institute. Source: Photo by Rich Earth Institute.

Section 4: Public Outreach

Demonstration toilet at REI headquarters in Brattleboro, Vermont. Source: capecodecotoiletcenter.com

Above: Public event to share research findings with public hosted by REI in downtown Brattleboro venue; Bottom left: High-fives exchanged by a family after using the public installation of a urine-only porta-potty at regional fair; Bottom right: Website and public relations development. All photos by Rich Earth Institute

APPENDIX C

FALMOUTH ECO-TOILET PROJECT PHOTO DOCUMENTATION

Flyer for the first Eco-Toilet Summit in March 2011. Source: cleanwaterfund.org; Flyer for the second Eco-Toilet Summit in July 2011. Source: cloacina.org.

Educational programming at the Cape Cod Eco-Toilet Center

Above: Eco-toilet advocate Hilde Maingay gives a tour at the Cape Cod Eco-Toilet Center. Source: capecodwave.com; Below: A visitor tests a toilet seat at the showroom. Source: capecodecotoiletcenter.com

A Dubbleton UD flush toilet installed in a participating household

Left: Dubbleton toilet installed for the project in a house that could only accommodate urine diversion and not a full composting toilet; Right: Eco-toilet advocate Matt Patrick shows off the urine-diverting flush toilet model that has worked for his family, but could be improved with a better flush mechanism. Photos by C. Bryars.

APPENDIX D

FALMOUTH ECO-TOILET VENDOR LIST

The following companies have composting toilet products that are approved as "alternative systems" by the Massachusetts Board of Plumbers and Gas Fitters:

Advanced Composting Systems/Phoenix (contact: Ben Goldberg, 413.586.3699 ben@compostingtoilet.com; www.compostingtoilet.com)

Clivus Multrum (contact: Lisa Truchon, 978.794.9400 http://clivusne.com/costs-residential-bathrooms.php)

Eco-tech/Carousel (contact: David DelPorto 978.338.4000, www.ecological-engineering.com/carousel.html or http://ecotechproducts.net/)

Sun-Mar (sold through ACE Hardware, 150 Main St. Falmouth, Ma. 508.548.0407) http://www.sun-mar.com/index.html)

Sancor Industries/Envirolet (sold online: http://www.envirolet.com/1.800.387.5126)

The following systems have been approved for use in Falmouth under a "Test Site" permit from the Massachusetts Board of Plumbers and Gas Fitters:

Dubletten urine-diverting fixture (contact Stubby Warmbold at: 908.735.8871 http://www.dubbletten.nu/wc-dubbletten-en.html)

Worstman/EcoFlush urine-diverting fixture (contact Carol Steinfeld- Ecovita at: 978.318.7033 www.ecovita.net)

Separett urine-diverting composting system (http://www.separett-usa.com/) Distributors include Ben Goldberg 413.586.3699, Carol Steinfeld 978.318.7033, and others listed on the Separett website)

Aquatron Composting System (contact Stubby Warmbold at: 908.735.8871, http://www.aquatron.se/index-2.php)

Full Circle Composting System (contact Abe Noe-Hayes at: 802.387.5357 (http://fullcirclecompost.org/)

*Error in pamphlet: Product listed as "Worstman" above is actually "Wostman"

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